

*Accipiter
gentilis*

FRENCH:
Autour des palombes
SPANISH:
Gavilán azor

Northern Goshawk

The Northern Goshawk (hereafter referred to as Goshawk) is a large forest raptor, occupying boreal and temperate forests throughout the Holarctic. In North America, it breeds from Alaska to Newfoundland and south (Fig. 1). This partial migrant winters throughout its breeding range including occasionally the Great Plains and southeastern states; some individuals undergo short movements to lower elevations during winter, apparently in search of food. Irruptive movements of northern birds to the south occurs at approximately 10-year intervals that coincide with population lows of snowshoe hare (*Lepus americanus*) and grouse.

Largest of the three North American accipiters, the Goshawk is a powerful hunter capable of killing a variety of prey, including tree squirrels, hares, grouse, corvids, woodpeckers and large passerines such as American Robins (*Turdus migratorius*). When

The Birds of North America

Life Histories for
the 21st Century

breeding, the female generally defends the nest while the smaller male provisions the family with food. Foraging males rapidly traverse large home ranges when searching for prey. Goshawks are well adapted for hunting in forests but also hunt open habitats. They are short duration sit-and-wait predators, perching briefly while searching for prey before changing perches. Their short, powerful wings allow rapid acceleration and their long tails quick maneuverability in trees. As an aggressive North American hunting hawk, Goshawks eagerly crash through brush when

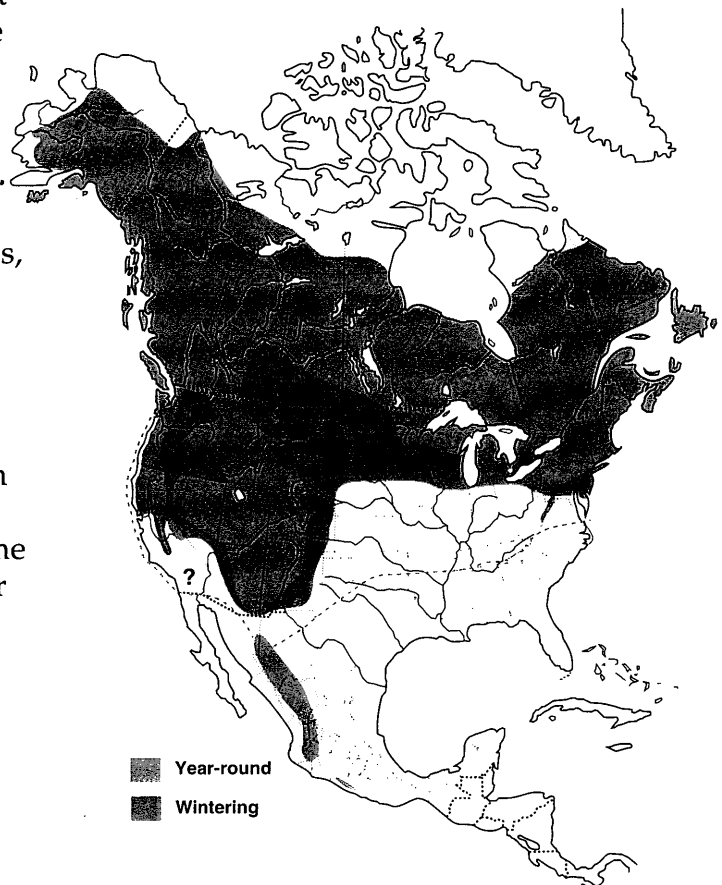
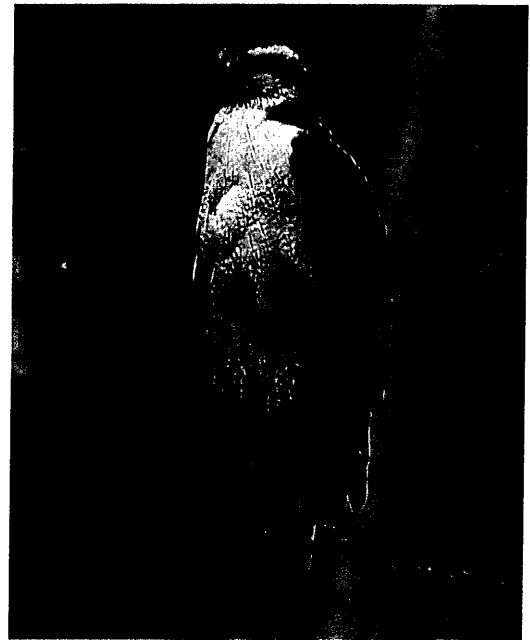


Figure 1.
Distribution of the Northern Goshawk in North America. Breeding distribution in Nevada and southern California is poorly known. This species winters irregularly south to the dotted line.

capturing prey or readily strike intruders approaching their nests.

Although Goshawks nest in a variety of habitat types—from willow stands along Arctic rivers to massive old-growth forests of the Pacific Northwest—they seem to prefer mature forests with large trees on moderate slopes with open understories. They nest in either coniferous, deciduous, or mixed-pine forests, depending on availability. Nest trees are usually one of the largest trees in the nest area; most territories contain several alternative nest trees.

Whether carried afield on the fists of Japanese shoguns or by medieval falconers of Europe, Goshawks have seen much human history. Revered as symbols of strength, a Goshawk adorned the helmet of Attila the Hun. The courage and extreme aggression of this species when hunting grouse, ducks, rabbits, and hares helped gain its reputation as the “cook’s hawk” among falconers. However, reverence changed to persecution when guns replaced trained hawks as the preferred means of providing game. Currently, the species is not listed as Endangered in U.S. but there is concern that timber harvest and human encroachment are reducing some populations.

Since the early 1970s, research has resulted from concerns about the effects of forest management on populations (Reynolds et al. 1982, Moore and Henny 1983, Reynolds 1983). Crocker-Bedford’s (1990) contention that populations in the Southwest were dropping precipitously catalyzed additional research by state and federal agencies. Most research in North America has discussed habitat-use patterns, home-range characteristics, food habits, productivity, and demography. European studies provide insights regarding migration, winter biology, behavior, and predator–prey relationships.

DISTINGUISHING CHARACTERISTICS

Large forest hawk with long, broad wings and long, rounded tail. Female larger than male: average total length, male 55 cm, female 61 cm (Wood 1938); wingspan, male 98–104 cm, female 105–115 cm (Wheeler and Clark 1995); mass, male 631–1,099 g, female 860–1,364 g (Appendix 2). Upperparts of adult brown-gray to slate gray; head with black cap and pronounced white superciliary line; underparts light gray with fine horizontal vermiculations and fine black vertical streaks. Undertail-coverts white, often quite fluffy, especially during courtship or when alarmed. Tail dark gray above with inconspicuous broad, dark bands (3–5); rounded tail tip may have thin white terminal band (reduced or absent with wear). Female similar to male but browner above and more coarsely marked below, sometimes appearing barred. Feet, cere, toes, legs, and mouth-lining yellow; eye red. For Juvenal plumage, see Appearance: molts and plumages.

Among North American accipiters, largest and heaviest bodied, appearing deep-chested with relatively broad wings and relatively short tail; wings appear tapered when soaring and pointed when flapping or stooping (Wheeler and Clark 1995). Clearly larger than Sharp-shinned Hawk (*Accipiter striatus*); in flight, head protrudes more on Goshawk, and tail broader and more rounded at tip. Male Goshawk may appear similar in size to female Cooper’s Hawk (*Accipiter cooperi*), although note differing wing and tail proportions above. Juvenile Goshawk differs from juvenile Cooper’s Hawk in having more conspicuous pale superciliary line, more heavily streaked belly-, underwing-, and undertail-coverts, slightly wedge-shaped tail, and tawny bar across upperwing. Subtle pattern of fine white lines outline dark bands on upperside of juvenile Goshawk’s tail, which, when spread, shows staggered dark bars in zigzag pattern rather than even banding of juvenile Cooper’s Hawk. Preceding characteristics based on Mueller et al. (1979), Kaufman (1990), and Wheeler and Clark (1995). Deep chest and pointed wings, sometimes seen on Goshawk, may suggest gray morph Gyrfalcon (*Falco rusticolus*), which has different flight action (not as rapid) and two-toned underwing with paler, inconspicuously barred, flight feathers contrasting with darker wing linings.

DISTRIBUTION

THE AMERICAS

Breeding range. ALASKA AND CANADA. Breeds from western and northern portions of central Alaska, n.-central Yukon, nw. and se. Mackenzie, s. Keewatin (Godfrey 1986), n. Ontario (Cadman et al. 1987), n.-central Quebec, n. Labrador, and Newfoundland (Godfrey 1986) south along the Pacific Coast (including Kodiak I., the Queen Charlotte Is., and Vancouver I.; Campbell et al. 1990) and Atlantic Coast (including Anticosti I., Prince Edward I., and Cape Breton I.; Erskine 1992) to s. Canada, excluding se. Alberta (Semenchuk 1992), s. Saskatchewan (Smith 1996), extreme s. Manitoba (Godfrey 1986), and southernmost Ontario (Cadman et al. 1987).

WESTERN U.S. Breeds from mountains of n. and w. Washington south through mountains of w. Oregon (Cascade and Siskiyou Mtns. and rarely to Coast Mtns.; Gilligan et al. 1994, DeStafano and McCloskey in press) and California (Siskiyou Mtns. south through North Coast Range, from Warner Mtns. south through Cascade and Sierra Nevada Mtns. to Greenhorn Mtns., the White Mtns., mountains of Kern and Ventura Cos. and possibly other southern counties; Small 1994). Also breeds from w. and s. Montana (Bergeron et al. 1992) and Idaho (except southwest; Stephens and Sturts 1991), south through Wyoming (except southeast; Oakleaf et al. 1992), Utah, and the western half of

Colorado (Andrews and Righter 1992) to n.-central and sw. New Mexico (Hubbard 1978), and nw. and se. Arizona (Monson and Phillips 1981, K. Kaufman pers. comm.). Additional breeding occurs in mountains of ne. and se. Oregon (Gilligan et al. 1994), insular mountain ranges of Nevada (Herron et al. 1985), the Cypress Hills of sw. Saskatchewan (Smith 1996), n.-central Montana (Bergeron et al. 1992), the Black Hills of w. South Dakota (South Dakota Ornithol. Union 1991), and the Sacramento highlands of s.-central New Mexico (Hubbard 1978).

EASTERN U.S. Breeds from Canadian border south to e.-central Minnesota (Janssen 1987), n. Wisconsin (Robbins 1991), the n. Lower Peninsula of Michigan (Brewer et al. 1991), central Pennsylvania (Brauning 1992), extreme nw. New Jersey (Speiser and Bosakowski 1984), se. New York (Andrle and Carroll 1988), w. and n. Connecticut (Bevier 1994), and se. Massachusetts (Veit and Petersen 1993). Also breeds in the Appalachian Mtns. of extreme w. Maryland (Robbins et al. 1996) and e. West Virginia (Buckelew and Hall 1994).

MEXICO. Breeds from easternmost Sonora and w. Chihuahua south to Jalisco and in s. Guerrero (Howell and Webb 1995).

Winter range. Resident throughout breeding range but with a portion of the population regularly wintering outside this area. Migrants travel various distances but observed most years south to n. Sacramento Valley and foothills of Cascade and Sierra Nevada Mtns. of California (Small 1994), central Arizona (Monson and Phillips 1981), sw. and ne. New Mexico (Hubbard 1978), e. Colorado (Andrews and Righter 1992), s. South Dakota (South Dakota Ornithol. Union 1991), n. Illinois (Bohlen 1989), n. and ne. Ohio (Peterjohn 1989), and s. New Jersey (Sibley 1993). During irruption years, larger numbers winter outside of breeding range and travel greater distances, reaching s. California (Small 1994), the Lower Colorado River Valley (4 records; Rosenberg et al. 1991), n. Texas (Oberholser 1974), central Oklahoma (Baumgartner and Baumgartner 1992), Arkansas (4 birds shot or recovered in state plus several unconfirmed observations; James and Neal 1986), Tennessee (≥ 45 records), especially along Appalachian Mtns. (Robinson 1990), and central Virginia. Individuals casually recorded south to Gulf Coast (Oberholser 1974) and w.-central Florida (Am. Ornithol. Union 1983); Christmas Bird Count data suggests species generally avoids se. U.S. (Root 1988).

OUTSIDE THE AMERICAS

Resident in Eurasia including British Isles, Scandinavia, n. Russia and Siberia, south to Mediterranean region, Asia Minor, Iran, Himalaya Mtns., e. China, and Japan (Am. Ornithol. Union 1983). Accidental in Ireland, Israel, Jordan, Egypt, Libya, Tunisia, and Algeria (Wattell 1973, Cramp and Simmons 1980).

HISTORICAL CHANGES

Few data; western and northern portions of range in North America probably relatively unchanged since settlement by Europeans, but extinction of Passenger Pigeons (*Ectopistes migratorius*) may have reduced Goshawk populations in e. North America (Bent 1937). Cutting of eastern forests may also have reduced eastern populations, but these may be recovering as reforested areas mature (Speiser and Bosakowski 1984); distribution expanding in Connecticut (Bevier 1994), New York (Andrle and Carroll 1988), Pennsylvania (Brauning 1992), and Michigan (Brewer et al. 1991). During mid-1950s, nesting restricted to w. Massachusetts, but species now nests throughout the state (Veit and Petersen 1993). In Minnesota, formerly restricted to southeastern regions, but now expanding northward and westward into e.-central, central, northeast and n.-central regions (Janssen 1987).

FOSSIL HISTORY

Data few; (possibly) ancestral stock spread from Europe to North America (Wattell 1981, Palmer 1988). This assumption based on close relatives of *Accipiter gentilis* existing in Africa (Black Sparrowhawk, *A. melanoleucus*) and Madagascar (Henst's Goshawk, *A. henstii*). Pleistocene fossils from genus *Accipiter* recovered from Russia, Europe, Asia, North America, and Mauritius (Romer 1966). In North America, Pleistocene fossils (Brodkorb 1963) of Goshawks recovered in California (Carpinteria, Rancho La Brea). Goshawk remains recovered from prehistoric pueblos (approx. A.D. 1325) in New Mexico (Emslie et al. 1992).

SYSTEMATICS

GEOGRAPHIC VARIATION

Clinal variation in size and coloration, with size (10 anatomical characters) decreasing from largest in sw. U.S. north to Pacific Northwest (smallest on Queen Charlotte Is.) and then increasing from Pacific Northwest northward through Canada to Alaska (Whaley and White 1994); coloration darkening to south and in Pacific Northwest, the change in color involving the extent and blackness of the crown and darkness of gray on back and wings. A subsequent analysis (excluding *A. laingi*) of wing cord as described by Whaley and White was confirmed; mass increases from south to north in w. North America (S. Rayroux and P. Kennedy unpubl. data). However, Eurasian Northern Goshawk vary from smaller south to larger north (Palmer 1988). Populations from eastern and western North America similar in size (excluding Alaska). In British Columbia, wing and culmen length of individuals measured from coastal islands are 2–3% smaller than those of birds from adjacent mainland (Johnson 1989). Fall migrants from the Goshute Mtns., NV, weighed significantly less

but had longer wings and tails than those from Cedar Grove, WI (Smith et al. 1990). Lighter wing loading of western versus eastern Goshawks may be an adaptation for longer migratory movements (Smith et al. 1990, Whaley and White 1994), but few data document differences in the extent of migratory movements of these populations.

SUBSPECIES

Ten weakly differentiated subspecies recognized by Stresemann and Amadon (1979), including 3 in North America. Because much of the variation is clinal, the validity of these subspecies is debated, and only 2 subspecies are recognized for North America by Am. Ornithol. Union (1957) and Palmer (1988). North American birds differ in Definitive plumage from Eurasian birds, which are more neutral colored dorsally (less bluish), have wider and more obviously barred pattern on underparts, and tend to have an orange to scarlet-orange eye color (vs. deep red) as adults (Palmer 1988); one race in e. Siberia has white morph.

Accipiter gentilis atricapillus (Wilson) 1812, breeds throughout North America, except in areas occupied by other subspecies. Vagrants to the British Isles have been noted Oct–Feb (Cramp and Simmons 1980). *A. g. laingi* (Taverner) 1940, breeds on Queen Charlotte Is. and Vancouver I. and is characterized by its darker coloration overall, black of crown extending to interscapulars, sootier gray ventrally, especially across the breast, and smaller size (wing length [convex distance] adult males: $325.2 \text{ mm} \pm 2.2 \text{ SE}$ ($n = 24$; Johnson 1989). Distribution of *laingi* extends from Vancouver I. northward through insular British Columbia, insular (Alexander Archipelago) and coastal mainland Alaska north to Icy Strait and Lynn Canal (Webster 1988, Titus et al. 1994, Iverson et al. 1996). *A. g. apache* (van Rossem) 1938, resident from s. Arizona south locally in mountains of Mexico to Jalisco is darker dorsally, almost blackish, and larger. Recognition of this race has been debated, but it is recognized by Phillips et al. (1964), Wattel (1973), Hubbard (1992), and Whaley and White (1994). Description and distribution of Eurasian subspecies are described in Wattel (1973), Cramp and Simmons (1980), and Palmer (1988).

RELATED SPECIES

Relationships poorly understood. Henst's Goshawk is a powerful bird of Madagascar that is similar in general appearance to the European Goshawk (Brown and Amadon 1968); Meyer's Goshawk (*Accipiter meyerianus*) on Jobi, Gilolo, New Britain, and Solomon Is., and the Bürger's Goshawk (*A. bürgersi*) of New Guinea are both large accipiters resembling Northern Goshawks (Grossman and Hamlet 1964). Black Sparrowhawk of Africa also considered closely related (Brown and Amadon 1968).

MIGRATION

NATURE OF MIGRATION IN THE SPECIES

Poorly understood for North America. Data from migration stations (Mueller et al. 1977, Kjellén 1994), observations of year-round occupancy (Speiser and Bosakowski 1991, Doyle and Smith 1994), and radio telemetry (Alaska Department of Fish and Game 1993, Keane and Morrison 1994, Reynolds et al. 1994, Squires and Ruggiero 1995) all indicate this species is a partial migrant (see Berthold 1993). The degree to which populations are partially migratory may relate to food availability on breeding areas during winter. At Klutane, Yukon Territory, for example, Goshawks are year-round residents during periods of high snowshoe hare abundance but scarce in winter when hare densities are low (Doyle and Smith 1994). Some Goshawk populations may undergo only short winter movements to lower elevations or to more open habitat types. In Wyoming, adults migrate up to 346 km from nest to wintering area (JRS, unpubl. data). In Cape May, NJ, normally few adult males and no adult females observed except during invasion years, an observation suggesting that migrants are predominantly immatures (Sibley 1993). Irruptions from breeding range vary in magnitude but limited evidence suggests some hawks return to breeding range after such movements (Campbell et al. 1990). A few band returns suggest that some irrupting hawks return to breeding areas in years subsequent to irruptions (Evans and Rosenfield 1995, Campbell et al. 1990, Evans pers. comm.) but the extent this occurs is unknown. Winter movements of European Goshawk populations have been studied more thoroughly (e.g., see Marcström and Kenward 1981a for details).

TIMING AND ROUTES OF MIGRATION

Fall. Begins late Aug through Sep; peak numbers late Sep to mid-Nov, depending on year and location; usually ends by Dec (Mueller and Berger 1968). In interior Alaska, juveniles more mobile than adults, especially in early fall (McGowan 1975). Fledglings believed to migrate first, followed by older birds; considerable overlap between sex and age classes. In the Goshute Mtns. of ne. Nevada, peak numbers 20 Sep–19 Oct (1995; S. Hoffman unpubl. data). In Colorado, migrants common in fall, but no birds trapped after 4 Feb (Doerr and Enderson 1965). At Cedar Grove Ornithological Station, WI, twice as many juvenile males as juvenile females (Mueller et al. 1977); sex ratio of adults approximately 1:1 except in incursion year (1992–1993) when more females present. Peak movement of juveniles was during late Oct at Cedar Grove, peak adult movement in late Nov. In the Goshute Mtns., NV, Goshawks, like other accipiters, have multiple peaks in numbers of migrants, an observation suggesting partial segregation by age and sex (Hoffman 1992). Peak daily movements are usually

in the morning (Mueller and Berger 1973). Migrants generally appear at Hawk Mountain Sanctuary in Kempton, PA, between late Sep and early Dec, peaking in late Nov (Atkinson et al. 1996), and at Cape May, NJ, from early Oct almost through mid-Dec (Sibley 1993).

Migration routes poorly delineated. In e. U.S., migrates along northern shore of Great Lakes and southward down the Appalachian ridges, and along coast (Table 1). Largest flights recorded at Hawk Ridge, MN; possibly composed of Canadian birds moving southwest along Lake Superior before dispersing south. Birds from central Canada may move southeast to forests in Minnesota and Wisconsin to avoid the Great Plains, then continue south. Migratory routes for western populations poorly delineated and may extend across a broad front. Significant numbers may migrate along the Rocky Mtn. front through s. Alberta and Montana (Beebe 1974). Four birds banded at Hawk Ridge, MN, recovered 2,250–2,400 km away in the northeastern corner of British Columbia, indicating that some hawks that breed in northwestern parts of range may migrate in a largely easterly southeasterly direction (Evans and Rosenfield 1985, Campbell et al. 1990).

Spring. Poorly understood. An early migrant, but spring movements are far less pronounced than fall movements in most areas and more poorly documented. Begin late Feb, continuing through early or late May. At Derby Hill (e. Lake Ontario), peak flights usually 10 Mar to 10 Apr (Smith and Muir 1980). Birds nesting in Wyoming begin spring migration from winter territories primarily mid-Mar through early Apr (Squires and Ruggiero 1995).

MIGRATORY BEHAVIOR

Few data regarding how migrants respond to weather conditions, topographic characteristics, and habitat-use preferences in terms of stopovers and foraging habitats during migration. Like other accipiters, migrants probably follow low-pressure fronts and topographic characteristics like mountain ranges that promote gliding; but Goshawks also migrate through extensive nonforested habitat (JRS). Occasionally migrates into extreme head winds and during winter storms (JRS). An adult female, banded on 30 Sep on Hawk Ridge, MN, was recovered on 30 Nov in Louisiana (1,860 km); this move required an average daily flight distance of 31 km (Evans and Sindelar 1974).

CONTROL AND PHYSIOLOGY

Prey availability may primarily dictate the proportion of Goshawk populations that migrate and the selection of wintering areas (see Terrill 1990; also see Migration: nature of migration). Muller et al. (1977) speculates that juvenile females displace smaller males from the breeding range during fall and winter, forcing them to migrate. All age classes may migrate when

Table 1. Numbers of Goshawks sighted at the Goshute Mtns., NV; Hawk Mtn., PA; Hawk Ridge, MN; and Cape May, NJ, during fall migration.

Year	Goshute Mtns. ¹	Hawk Mtn. ²	Hawk Ridge ³	Cape May ⁴
1970		75		
1971		33		
1972		347	5,382	
1973		307	3,566	
1974		61	1,400	
1975		136	312	
1976		62	308	17
1977		85	110	22
1978		58	166	19
1979		68	326	16
1980		83	250	25
1981		138	981	34
1982		140	5,819	35
1983	112	129	1,999	40
1984	146	59	934	25
1985	119	50	584	75
1986	65	106	354	24
1987	63	57	203	20
1988	74	50	177	14
1989	83	27	106	9
1990	127	88	626	34
1991	147	54	1,007	55
1992	252	43	2,247	30
1993	120	109	1,393	80
1994	105	31	305	37
Mean	118	96	1242	32

¹S. Hoffman unpubl. data, Hawk Watch International.

²Hawk Mtn. Sanctuary Assoc. unpubl. data.

³David L. Evans unpubl. data, Hawk Ridge Nature Reserve.

⁴Cape May Bird Observatory unpubl. data.

prey are sparse. During 1972–1973 invasion, adult males were significantly lighter in mass and, for the first time, migrated earlier than females. In Fennoscandia, juveniles moved further than adults; juvenile males moved further than juvenile females during winters with longest snow cover (Marcström and Kenward 1981a). Low winter temperatures were associated with reduced juvenile survival. In central Sweden, late-winter decrease in body weight was associated with reduced survival (Marcström and Kenward 1981b). Females seemed more prone to mortality from food shortage than males.

HABITAT

BREEDING RANGE

Sea level to alpine; nests in most forest types found throughout geographic range. In eastern deciduous forests, Goshawks prefer nesting in mature, mixed

hardwood-hemlock stands of birch (*Betula* sp.), beech (*Fagus* sp.), maple (*Acer* sp.), and eastern hemlock (*Tsuga canadensis*; Speiser and Bosakowski 1987). In the Black Hills, SD, and throughout the sw. U.S., nests primarily in ponderosa pine (*Pinus ponderosa*) forests (Erickson 1987, Reynolds et al. 1994). Forest types used by other western Goshawk populations include Douglas fir (*Pseudotsuga menziesii*), various pines, and aspen (*Populus tremuloides*) (Reynolds et al. 1982, Younk and Bechard 1994, Siders and Kennedy 1996, Squires and Ruggiero 1996). In interior Alaska, paper birch (*Betula papyrifera*) was dominant in nest stands and was preferred over other tree species (McGowan 1975).

Forest stands containing nests are often small, approximately 10–100 ha (Reynolds et al. 1982, Woodbridge and Detrich 1994); territories may contain 1–5 alternative nest areas. In n. California, maximum distance between alternative nest stands was 1.8 km, and approximately 85% of alternate nest stands were <0.7 km apart (mean 0.52 km \pm 0.11 SE, n = 71 stands; Woodbridge and Detrich 1994). Depending on the continuity of forest cover, nests of adjacent pairs occur at regular intervals (Reynolds and Wight 1978, Reynolds et al. 1994). In saturated populations, the species composition and structure of vegetation in nest areas depend on availability within given territories. Thus, although Goshawks prefer certain nest habitat structures (see below), habitat characteristics in nest areas vary from territory to territory, depending on availability.

Descriptions of nest habitat may be biased because not all studies equally sample all habitats and forest successional stages for nesting hawks; data are equivocal regarding mature forest preferences. Although considered a habit generalist at large spatial scales, they tend to nest in a relatively narrow range of vegetation structural conditions. Nests are typically in mature to old-growth forests composed primarily of large trees (Reynolds et al. 1982, Speiser and Bosakowski 1987, Squires and Ruggiero 1996), with high (60–90%) canopy closure (Reynolds et al. 1982, Hayward and Escaño 1989, Siders and Kennedy 1994), near the bottom of moderate hill slopes, with sparse ground cover (Reynolds et al. 1982, Squires and Ruggiero 1996). Closed stands may reduce predation and, along with north slopes, provide relatively cool environments (Reynolds et al. 1982). Nest habitat is single to multistoried, depending on forest type (Reynolds et al. 1992, Squires and Ruggiero 1996). In eastern deciduous forests, Goshawks prefer to nest in large forested areas containing more mature timber than generally present in the landscape; smaller forest tracts seldom used (Bosakowski and Speiser 1994). In n. California, smaller nest stands (<10 ha) containing 1–2 nests were occasionally occupied, whereas occupancy of large stands (>20 ha) was more consistent; occupancy rate of nest stands was positively correlated with stand size (Woodbridge and Detrich 1994).

Goshawks nesting in high-elevation, shrub steppes in Nevada use small, scattered aspen stands of mature trees along drainages (Younk and Bechard 1994). Although mature forests are apparently preferred, young, vigorous, and even-aged forests with sparsely distributed mature and old-growth trees with high canopy coverage (mean 94% \pm 0.4 SE) were used in California (Hall 1984).

High canopy closure is one of the most uniform habitat characteristics of Goshawk nest stands (Hayward and Escaño 1989). In Arizona, if canopy coverage was between 60% and 69%, stands were used only 43% as often as expected on the basis of availability (Crocker-Bedford and Chaney 1988). Goshawks nested 2.5 times more often than expected in stands with 70% to 79% canopy coverage and 5.8 times more often than expected in stands with 80% or greater canopy coverage. Canopy coverage (n = 36 stands) in stands used by this population averaged 76% \pm 7 SD; 18% greater (p < 0.001) than the surrounding landscape. Although high canopy cover is apparently preferred, some populations use open forests (33%, Reynolds et al. 1982; 31% \pm 13 SD, Hargis et al. 1994). Goshawks also nest in tall willow communities along drainages in Arctic tundra (Swem and Adams 1992) and will use stands of trees that died of beetle infestation for at least several seasons (RTR).

Water. Free water—anything from a forest pond or small, ephemeral stream to a major river or large lake—is often present near nests (Bull and Hohmann 1994, Hargis et al. 1994) but is not a habitat requirement (Reynolds et al. 1982, Speiser and Bosakowski 1987, Crocker-Bedford and Chaney 1988). Goshawks bathe or wade in water, but the benefit, if any, is unknown (Brown and Amadon 1968); may help brooding Goshawks maintain proper humidity during incubation (Hennessy 1978). Tends to avoid nesting near cataracts of loud-rushing streams (Shuster 1980, Reynolds et al. 1982, Speiser and Bosakowski 1987). In California, permanent water was generally closer to nesting ranges than to the centers of random circles (Hargis et al. 1994). These water sources were incorporated into home ranges up to 3.5 km from nests.

Small forest openings. Openings may increase nest access, serve as travel corridors (Erickson 1987, Speiser and Bosakowski 1987), support open-country prey (Shuster 1980), or reduce flight barriers to fledglings (Hall 1984). In eastern deciduous forests, nests were significantly closer to wood roads and trails than to random points in the general landscape; this result was obtained despite extensive off-trail searching (Speiser and Bosakowski 1987). Small roads represented the only break in contiguous eastern forests. In Pennsylvania, however, Goshawks avoid nesting near light-duty roads but often nest near woodland trails (Kimmel and Yahner 1994). In Oregon, frequently nest near breaks in the canopy produced by logging trails, downed trees, or openings in understory conifers from

overstory shading (Reynolds et al. 1982). Mean distances of forest openings from nests vary: California, $85.3 \text{ m} \pm 107.1 \text{ SD}$ (most nests within 15 m, Saunders 1982); S. Dakota, 73.9 m (range 16.9–215 m, Erickson 1987).

Foraging habitat. Hunts in diverse habitats ranging from open-sage steppes to dense forests, including riparian areas. Evolved morphological adaptations for pursuing prey in forests, but broad wings with long wing-tip also adapted for ambushing prey in open habitats (Wattel 1973). Habitat-use preferences of foraging Goshawks poorly understood for North American populations. In n. Arizona, foraging sites were not selected on the basis of prey abundance but were in forests with greater canopy closure, and greater density of trees ($>41 \text{ cm dbh}$) relative to contrast plots (Beier and Drennan 1997); results consistent with the hypothesis that Goshawk behavior and morphology are adapted for hunting in moderately dense mature forests where prey are most vulnerable. Limited additional evidence also suggests that mature forests are preferred foraging habitat. In sw. Yukon Territory, 33% of Goshawk kills were in dense forests, even though this habitat covered only 18% of the valley (Doyle and Smith 1994). In n. Arizona, habitat preference increased with increasing canopy closure (Bright-Smith and Mannan 1994). In California, mature and old-growth habitat ($\geq 52 \text{ cm}$, canopy closure $\geq 40\%$) were used, whereas open habitats such as meadows and seedling and sapling stands were avoided (Austin 1993); a second California study found that nest sites and surrounding home range telemetry points had greater basal area, canopy cover, and trees in large diameter classes than did random plots (Hargis et al. 1994). However, some populations readily forage in open habitats. In Nevada, Goshawks foraged in open sagebrush or perched in edges of aspen groves to hunt ground squirrels in the adjacent sagebrush (Younk and Bechard 1992).

SPRING AND FALL MIGRATION

No data.

WINTER RANGE

Poorly understood; limited knowledge based mostly on European studies. During the winter in Sweden, Goshawks used a highly fragmented patchwork of clear-cuts and forest stands intermingled with wetlands and agricultural lands; no difference in distribution of relocations according to season (autumn, winter, and spring) among 6 habitat categories (clear-cuts, young forest 10–40 yr old, middle-aged forest 40–60 yr old, mature forest over 60 yr old, wetlands, and agricultural land) for males or females (Widén 1989). However, Goshawks did significantly prefer mature forests, which contained $>50\%$ of kills. Large habitat patches ($>40 \text{ ha}$) of mature forests were especially used; young and middle-aged forests avoided. Mature forests may

provide sufficient cover to attain hunting perches undetected, yet are open enough for hawks to maneuver when attacking prey (Widén 1989). Agricultural lands, wetlands, and clear-cuts used in proportion to availability. Although mature forests were preferred by Goshawks wintering in Swedish boreal forests, edge habitats were used extensively by birds wintering in agricultural lands (Kenward and Widén 1989). These habitat-use differences are attributed to different prey distributions; Goshawks in boreal regions feed primarily on squirrels that are distributed throughout the habitat, whereas prey in agricultural areas are primarily near edge zones. Prey abundance, not woodland habitat, may primarily determine habitat preferences of wintering Goshawks.

In the Rocky Mtns., wintering Goshawks use cottonwood riparian areas (Squires and Ruggiero 1995), aspen, spruce/fir, lodgepole pine, ponderosa pine, and open habitats (JRS).

FOOD HABITS

FEEDING

Main foods taken. Opportunist; kills a wide diversity of prey, depending on region, season, vulnerability, and availability. Main foods include ground and tree squirrels, rabbits and hares, large passerines, woodpeckers, game birds, and corvids; occasionally reptiles and insects (see Diet, below).

Foraging behavior. Foraging individuals travel through the forest in a series of short flights, punctuated with brief periods of prey searching from elevated hunting perches (short duration sit-and-wait predatory movements). During the winter, European Goshawks killed approximately twice every 3 d (Kenward 1979). In Sweden, interperch flights averaged 84 s for males and 96 s for females (median flight length 24 s for males and females; Widén 1984). Foraging males remained perched for an average of 8 min, 36 s; 10 min, 24 s for females (median perch time 3 min for both). Flight activity increased with increased hunger. In New Mexico, median flight time was 3.5 min for males ($n = 3$) and females ($n = 5$; Kennedy 1991).

Food capture and consumption. Occasionally, Goshawks hunt by flying rapidly along forest edges, across openings, and through dense vegetation to surprise prey (Johnsgard 1990); also attack prey in flight (Kenward 1982; see Fig. 2). May stalk prey on foot, using vegetation and topography for concealment (Bergstrom 1985, Backstrom 1991) or may capture prey through dogged persistence. In Arizona, captured Abert's squirrels (*Sciurus aberti*) after 10–15 min by persistently chasing squirrels from branch to branch through the tree (Westcott 1964). A Goshawk chased a snowshoe hare along a hedgerow for 45–60 min before the hare finally ran across an opening and was captured (Brace 1983).

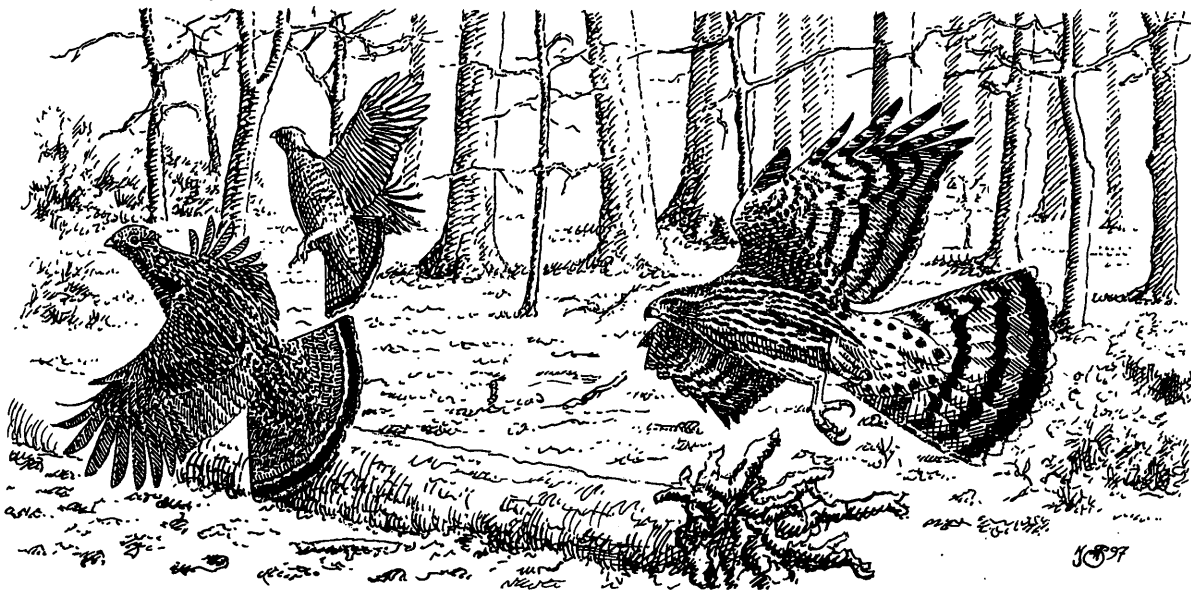


Figure 2. Northern Goshawk attacking a Ruffed Grouse. Drawing by N. John Schmitt.

Most Goshawk prey occupy the ground-shrub zone (Reynolds and Meslow 1984). If undetected by prey, the hawk's attack may consist of a smooth, silent, accelerating glide that ends in a capture strike without a wing beat (Beebe 1974). If spotted by prey, the hawk rapidly pumps its wings to close in on the intended quarry. Readily crashes through shrubs and vegetation or will enter water when chasing prey (Schnell 1958, Fulton 1983); reckless nature when hunting is legendary among falconers (Beebe 1974). Flights on winged quarry rarely last >1 km before the hawk overtakes its prey. Surprise affects hunting success. In experimental Goshawk flights on wood pigeon flocks, attack success decreased significantly with increased response distance (i.e., pigeons became aware of the hawk sooner; Kenward 1978). Filmed attacks of captive Goshawks striking pigeons indicate that the hawks begin their final glide 7.6–9.1 m from prey; at 1.5–2.4 m they lower their feet with toes partially flexed (Goslow 1971); near impact, legs are extended and feet held well out in front of attacking bird; toes fully extended when 76–89 cm from the prey. At impact, foot velocities of 2,250 cm/s were 15% greater than the pelvis velocity. Maximum speeds attained by a Goshawk during two stoops at a Honey Buzzard (*Pernis apivorus*) were 23.9 m/s and 24.2 m/s (Alerstam 1987). Goshawks kill prey by driving their talons into the quarry, using a kneading action immediately after impact; their strong feet and bill are capable of killing a wide variety of large-bodied prey.

Plucking perches. Some perches near nests are used repeatedly for plucking prey. Plucking perches may be downed logs, stumps, or old nests; preferred perches are low (usually <1 m), bent-over trees or saplings (Schnell 1958, Reynolds and Meslow 1984, Bull and

Hohmann 1994). Plucking perches are usually located in denser portions of the secondary canopy and are often up-slope and fairly close to the nest (Hall 1984). Average distances from nests were, in Oregon, 45 m (range 27–74 m; Reynolds et al. 1982); in ne. Oregon, 42 m (range 7–200 m; Bull and Hohmann 1994); in California, 69 m (range 30–130 m; Schnell 1958). Known distances to plucking perches may be biased because observers often search only near nests or have difficulty locating distant sites.

DIET

Major food items. Forages over long distances for relatively large-bodied birds and mammals; especially vulnerable prey are young of the year. In Oregon, average prey mass was 307 g \pm 364 SD (range 17.6–1,505 g; Reynolds and Meslow 1984). Average avian prey mass was 195.5 g \pm 207 SD (range 17.6–1,505.0 g); and average mammalian prey mass was 445.2 g \pm 415 SD (range 36.8–1,118.6 g). On the Kaibab Plateau, AZ, the average mass for avian prey was 79.2 g and for mammalian prey, 377.5 g (C. W. Boal and R. W. Mannan unpubl. data). Males can kill prey 2.2 times their mass (approximately 1,600 g), which is proportionally similar to the largest hares (2,700–3,670 g) killed by females (2.4 \times female mass; Kenward et al. 1981a). Occasionally Goshawks feed on carrion (Sutton 1925, Squires 1995).

Southern populations may depend less on mammalian prey than northern populations, but there are exceptions (Table 2; Boal and Mannan 1994). Although potential prey species are extensive (Appendix 1), a few taxa are particularly prevalent in most diets. Dominant mammalian prey include tree squirrels (Douglas squirrel [*Tamiasciurus douglasii*], red squirrel [*T. hudsonicus*], gray squirrel [*Sciurus carolinensis*],

Table 2. Proportion of mammalian and avian prey in diets of Northern Goshawk during the nesting season.

Location	Percentage of mammalian prey (biomass)	Percentage of avian prey (biomass)	Study
United States:			
Alaska	78 (90)	21 (10)	Zachel 1985 ¹
Arizona	76 (94)	24 (6)	Boal and Mannan 1994 ³
Arizona	62	38	Reynolds et al. 1994 ^{1,2}
California	32	68	Bloom et al. 1986 ²
Nevada	67	32	Younk and Bechard 1994 ³
New Mexico	49	51	Kennedy 1991 ¹
New York	39	61	Grzybowski and Eaton 1976 ²
Oregon	42	59	Bull and Hohmann 1994
Oregon	45	55	Reynolds and Meslow 1984 ^{1,2}
Utah	82	18	Lee 1981 ^{1,2}
Canada:			
Yukon	— (86)	— (13)	Doyle and Smith 1994 ²
Sweden	21.3 (15.2)	78.6 (84.8)	Widén 1982 ²
¹ Pellet analysis.			
² Prey remains.			
³ Direct observation.			

tassel-eared squirrel [*S. aberti*], northern flying squirrel [*Glaucomys sabrinus*]; ground squirrels (golden-mantled ground squirrel [*Spermophilus lateralis*], Richardson's ground squirrel [*S. richardsonii*], Belding's ground squirrel [*S. beldingi*], Townsend's ground squirrel [*S. townsendii*]); and lagomorphs (cottontails [*Sylvilagus* sp.], jackrabbits [*Lepus* spp.], and snowshoe hare [*Lepus americanus*]). Dominant avian prey include galliformes (Blue Grouse [*Dendragapus obscurus*], Spruce Grouse [*D. canadensis*], Ruffed Grouse [*Bonasa umbellus*]); corvids (Blue Jay [*Cyanocitta cristata*], Steller's Jay [*C. stelleri*], Gray Jay [*Perisoreus canadensis*], American Crow [*Corvus brachyrhynchos*]); piciforms (Williamson's Sapsucker [*Sphyrapicus thyroideus*], Pileated Woodpecker [*Dryocopus pileatus*], Black-backed Woodpecker [*Picoides arcticus*], Three-toed Woodpecker [*P. tridactylus*], Hairy Woodpecker [*P. villosus*], and especially Northern Flicker [*Colaptes auratus*]); and various passerines, especially American Robin (*Turdus migratorius*).

Little is known regarding seasonal changes in diet composition. During nesting, diets may shift to include more fledgling passerines (Lindén and Wikman 1983, Reynolds and Meslow 1984, Zachel 1985, Tornberg and Sulkava 1990). Diet diversity may peak during nestling stage when juvenile birds become available (Wikman and Tarsa 1980, Marquiss and Newton 1982). In Nevada, Goshawks ate more birds such as American Robins and Northern Flickers in midsummer when

Belding's ground squirrels began estivation (Younk and Bechard 1994). In Arizona, there was no significant difference in proportions of mammalian and avian prey taken throughout the nesting season (Boal and Mannan 1994).

Diet composition may change drastically from breeding to nonbreeding seasons. In Swedish boreal forests, birds dominated the diet during nesting, accounting for 86% of prey number and 91% of biomass (Widén 1987). However, red squirrel (*Sciurus vulgaris*) was the dominant prey both in terms of numbers (79%) and biomass (56%) during the winter. The proportion of squirrel in Goshawk diets was high in winters of both high and low squirrel numbers. Seasonal dietary shifts are at least partially due to different migration, estivation, and hibernation behaviors among suites of prey.

Quantitative analysis. Appendix 1. Diet information is primarily from nesting season; winter food habits are unknown for North American populations.

FOOD SELECTION AND STORAGE

Most prey are 250–450 g in mass; generally larger than prey eaten by either Sharp-shinned or Cooper's hawks (Reynolds and Meslow 1984, Bosakowski et al. 1992), but there are exceptions (Kennedy 1991). In Oregon, Goshawk prey were significantly heavier (306.6 g \pm 363.9 SD) than quarry eaten by Cooper's Hawks (134.7 g, nw. Oregon; 136.3 g, e. Oregon) or Sharp-shinned Hawks (12.8 g, nw. Oregon; 28.4 g, e.

Oregon; Reynolds and Meslow 1984). Some Goshawk populations select a higher proportion of mammalian prey than do neighboring Cooper's Hawks (Lee 1981, Bosakowski et al. 1992).

Cached prey are placed on a branch near the tree trunk or wedged in a crotch between branches (Zachel 1985). Goshawks cache food primarily when nestlings are small and need frequent feedings; caching may cease when young are >1 mo old (Schnell 1958). Most cached items are fed to young the same day, but some at least 32 h after a kill (Schnell 1958).

NUTRITION AND ENERGETICS

From fall to spring, a captive adult male Goshawk (880 g) consumed 14.1% of its body weight (mean = 124 g) daily at an average temperature of -2°C (Fevold and Craighead 1958). Captive Goshawks ($n=4$, housed at 22°C) ate 30.8 g dry food/kg body mass/d ± 6.3 SD ($n=26$ observations) and 27.6 g/kg/day ± 9.1 SD ($n=101$) when fed at 09:00 and 11:00, respectively (Duke et al. 1976). Male wintering Goshawks in Sweden consumed approximately 133 g/d and females 189 g/d (Kenward et al. 1981a).

Marcström and Kenward (1981b) estimated males and females require 176 kcal/d and 224 kcal/d of food, respectively. Males and females at 20% above mean winter mass could fast at 0°C for 6 and 8 d, respectively. Body condition of females increased from fall to spring, whereas that of males declined (Widén 1985). Both sexes were similar in body condition from fall to winter, but females improved condition during the spring relative to males. During the nonbreeding season in Sweden, adults and juveniles of both sexes increased in weight from Aug to Nov (Marcström and Kenward 1981b). Juvenile male mass remained fairly constant, except for slight increases in Feb and Mar, whereas adult males reached peak mass in Jan before declining slightly. Mass of females declined during midwinter, especially for juveniles, followed by a recovery in Feb and Mar.

METABOLISM AND TEMPERATURE REGULATION

Rates of metabolic heat production in a post-absorptive male Goshawk (751 g) was 4,289 mW and 3,621 mW for a female (958 g, Kennedy and Gessaman 1991). Large accipiters had significantly higher rates of metabolic heat production than smaller species; accipiters in general tend to have higher metabolic rates than other falconiforms of similar size because of high activity levels.

DRINKING, PELLET-CASTING, AND DEFECATION

Although water sources are often associated with nests (see Habitat: breeding range), Goshawks use of water for drinking is unknown. Pellets are usually cast between 06:30 and 08:30, apparently stimulated by first light of day (Duke et al. 1976); meal to pellet interval averaged 21 h ± 2.45 SD ($n=9$).

SOUNDS

VOCALIZATIONS

Mostly silent, but vocal during courtship and nesting. May also vocalize when chasing prey (Zirrer 1947). Like other accipiters (Rosenfield and Bielefeldt 1991), probably depends on vocalizations for communication in forested habitats with limited visibility. Both sexes have an equally varied repertoire (Palmer 1988), but male's voice is higher and less powerful (Sutton 1925, Allen 1978). Vocalizations similar to those of Cooper's or Sharp-shinned Hawks, but louder and fuller (Palmer 1988).

Development. Four- to 9-d-old nestlings give a Whistle-Beg call when fed (Schnell 1958, Boal 1994a). At 11 d, chicks utter a rapid, high-pitched twitter when in pain (caught in a branch) and 19-d-old birds vocalize high-pitched Contentment Twitter that consists of staccato notes with uneven rhythm when content and well fed (Schnell 1958). Nestlings begin Food-Begging call at 21 d of age; at approximately 1 mo, they vocalize an aggressive *ke-ke-ke* that evolves into the adult's *kakking* attack call by approximately 40 d of age. Fledglings are quite vocal, often Wail-calling for long periods, especially when hungry.

Vocal array. When alarmed, either sex utters *ki-ki-ki-ki* or *kak, kak, kak* in a rapid series of about 10–20 calls (Fig. 3). Sometimes the call begins with a drawn-out *kree-ya* and may occasionally end with a *kuk*. When mobbing a predator such as a Great Horned Owl (*Bubo virginianus*) or defending the nest, the female's voice may lower slightly in pitch and become harsh and rasping. As the intensity of her attacks increases, *kakking* becomes more rapid and can attain a constant screaming quality. Females often perch in treetops when fatigued, and their calls are spaced at longer intervals. Perched birds usually turn their head back and forth when calling, creating the illusion that sounds are coming from different directions. Males also utter alarm calls when attacking intruders but at a higher pitch and with less intensity than females. Both sexes engage in intense *kakking* during copulations.

Both sexes utter a plaintive Wail call (*kree-ah*) that lasts about 1–2 s. Calls are irregular but frequent, and are single rather than in sequence (Beebe 1974). Functions of Wail calls (3 variants) appear to differ according to context (Schnell 1958). Males and females often call to one another (Recognition Wail) when the male enters the stand. When the male returns to the nest with food, the female leaves the nest and both adults Recognition Wail to one another. As the male approaches, the female emits a Food-Transfer call that is similar to a Recognition Wail but with shorter, more intense notes that end in a harsh-sounding falsetto or chatter. The third variant is a Dismissal Wail that is similar to the Recognition Wail but is given with less vigor. The first note is usually half the length of the others, with approximately 0.5 s

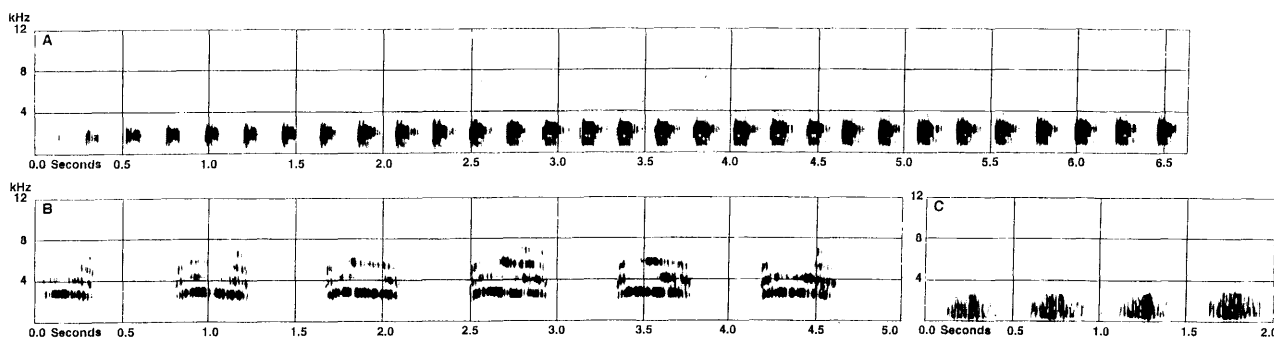


Figure 3. Northern Goshawk vocalizations: (A) Alarm call (female, provided by Kevin McCray); (B) Food-Begging Wail call (female, Kevin McCray); (C) Wail call (female, recorded on 6 Apr 1988 at Oconto Co., WI, from the collection of the Borror Laboratory of Bioacoustics [BLB] #16899). Sonograms produced by the staff of the BLB, Ohio State University.

between calls. Female may continue to call until male leaves the area.

Male also gives a *kek*, *guck*, or a *chuuck* single-note call as he enters the nest stand with prey (Sutton 1925, Palmer 1988, JRS). It is an unmusical note, like snapping the tongue away from the roof of the mouth while the head is brought abruptly downward (Schnell 1958). This call appears to announce the male's presence and location. Females are usually very responsive to this call; often, prey is then immediately transferred with a Food-Transfer call. This call is easy to overlook in the field, because males often only vocalize once or twice when entering their nest stands (JRS).

Phenology and daily pattern. Little information. During courtship, the male awakens and gives a *ki-ki-ki-ki* (long series) to the female (Palmer 1988). The Dawn call is a series of woodpecker-like clucks that are closely and evenly spaced (Beebe 1974).

Places of vocalizing. See Vocal Array.

Social context and presumed functions of vocalizations. See Vocal Array.

NONVOCAL SOUNDS

None known.

BEHAVIOR

LOCOMOTION

Walking, hopping, climbing, etc. Pursues prey by running into thick underbrush when necessary; even chases poultry into buildings. May wade into shallow water after prey such as ducklings (Schnell 1958).

Flight. Flight pattern typical of the genus; several rapid flaps followed by a glide, although wing beats are slower, deeper, and more direct than those of the Eurasian Sparrowhawk (*Accipiter nisus*; Cramp and Simmons 1980) and other North American accipiters (Kaufman 1990). Soars occasionally during migration and during courtship over nest stands. Highly agile when chasing prey; speed of flight through forests is

astonishing, given the large size of this species. Also see Food Habits: feeding.

SELF-MAINTENANCE

Preening, head-scratching, stretching, bathing, anting, etc. Preening similar to that of other raptors. Stretches by spreading tail sideways and holding it rigid, while leg is extended stiffly backward and held parallel under the tail; wing is extended downward and back while primaries are spread, partially covering the tail (Schnell 1958). Tail, leg, and wing are held taut for 3–5 s before regaining normal perched position.

Sleeping, roosting, sunbathing. Roosts alone in tree canopy. Several sites used for roosting, but roosting habitat not described. In early nesting phase, female roosts on nest while brooding young (Schnell 1958). Roosting birds readily fly when approached at night and can detect human intruders >100 m away on moonlit nights (JRS). Perched birds stand on one leg with the other drawn close to the breast between the feather tracts (Schnell 1958). The leg, with toes clenched, is raised and lowered, striking the perch several times, until it is abruptly drawn into the breast feathers.

Daily time budget. Diurnal. Activity begins approximately at first light (Schnell 1958); exact time varies according to season and latitude. Total percentage of time in flight for Goshawks nesting in New Mexico averaged 18.2% (3.8 CI) for males and 6.1% (3.4 CI) for females (Kennedy 1991). No diurnal rhythms of foraging activity; timing of hunting forays depend on the species and diurnal activity patterns of prey. In Utah, a male Goshawk spent approximately 108 min in direct flights and 67 min soaring per day (Fischer 1986).

No data on time budgets during the nonbreeding season for North American populations. During winter in Sweden, females become active 27 min before sunrise; males, 21 min before sunrise (Widén 1982). Male flight activity distributed throughout the day, totaling 7.1% of the daily activity pattern. Female flight activity peaked between 08:00 and 09:00; total flight time

slightly less than that of males (Widén 1982). Female activity coincided with squirrel activity (Widén 1984). Total flight time increased with time since last kill, especially for females.

AGONISTIC BEHAVIOR

Physical interactions. Intraspecific interactions not well understood.

Communicative interactions. Secretive throughout the year; often extremely aggressive when defending nests from intruders. High-circling displays (see Sexual Behavior: pair bond, below); neighboring pairs may circle together above their territories without apparent hostility (Forsman and Solonen 1984). Soaring occurs throughout breeding season but especially common during incubation in mid-to-late mornings. Adjacent territorial males soar above territories and approach one another mid-way between nests; soaring may function as territorial display (RTR). During incubation, males are secretive and females rarely flush to defend the site even when intruders are directly below the nest (Speiser and Bosakowski 1991, JRS). Aggression peaks during early-nestling stage, then wanes as young fledge (JRS).

Threat displays are similar to those of other hawks (Brown and Amadon 1968). Adults threaten by lowering their heads and crouching forward, raising crest feathers, partially spreading their wings and tail. Often accompanied by alarm calls. Large nestlings threaten intruders at nests by sitting back on tibiotarsal joint and tail, with wings spread, contour feathers erect (especially on head), gape open, and tongue protruding; may talon intruders if handled.

SPACING

Territoriality. Territorial against raptors, including other Goshawks, during nesting (Beebe 1974, Kostrzewa 1991). Readily kills neighboring raptors (Kostrzewa 1991), but may have little effect on productivity of some raptor populations (Dobler 1990). Postfledging area (PFA) may represent defended portion of territory (Reynolds et al. 1992), which includes approximately 170 ha surrounding the nest (Kennedy et al. 1994). Can strike and draw blood from persons approaching nests (Dixon and Dixon 1938, Zirrer 1947); attacks on a single person are usually more severe than those on two or more persons (Gromme 1935, Speiser and Bosakowski 1991). European Goshawks less aggressive toward human intruders, possibly due to long-term persecution. No data concerning winter territoriality.

Individual distance. Intraspecific nest spacing tends to be regular (Widén 1985, Dobler 1990, Kostrzewa 1991, Reynolds et al. 1994); clumping occurs near meadows and riparian systems (Woodbridge and Detrich 1994). Mean nearest-neighbor distance between nests $3.0 \text{ km} \pm 0.83 \text{ SD}$ (range 1.6–6.4 km, $n = 59$) in Arizona (Reynolds et al. 1994) and $3.3 \text{ km} \pm 0.3 \text{ SE}$

(range 1.3–6.1 km, $n = 21$) in California (Woodbridge and Detrich 1994). Average distance between nests in Oregon 5.6 km (Reynolds and Wight 1978), similar to spacing in Sweden (5.5 km, Høglund 1964; 6.3 km, $n = 4$ –9 pairs, 1977–1982, Widén 1985).

SEXUAL BEHAVIOR

Mating system and sex ratio. Apparently monogamous. Sex ratio 1:1 prior to fledging ($n = 23$ broods; Reynolds et al. 1994) and among adults (Mueller and Berger 1968, Marcström and Kenward 1981b, Widén 1985). Juvenile sex ratio, however, favors males (2.2 males, Mueller and Berger 1968; 1.9 males, Widén 1985; 1.4 males, Marcström and Kenward 1981b), perhaps owing to differences in trap vulnerability, habitat preference, or migratory habits (Widén 1985).

Pair bond. *COURTSHIP DISPLAYS AND MATE GUARDING.* During nest repair and construction, both pair members engage in Sky-Dance Display (Beebe 1974, Palmer 1988). From brief soaring flights, male dives at female with closed wings well above the forest canopy or initiates a direct aerial chase below tree canopy. Both birds then fly slowly about 1 m apart, with deep, slow wingbeats, wings held above body dihedral. Initial flight undulations may be shallow or can consist of spectacular dives. Zirrer (1947) describes this flight as wavy gliding approximately 3–6 m above the canopy; at times, pair members are close together and then far apart. Pair members may be silent during the display or may be highly vocal, uttering wails and chatters. White undertail-coverts may also be flared 10 cm on either side of the tail (Beebe 1974). Prey plucking (Schnell 1958), frequent copulations (Møller 1987), and conspicuous perching (Lee 1981) may also serve courtship functions.

COPULATION AND COPULATORY DISPLAYS. From Møller (1987), Palmer (1988). Copulations are short ($9.3 \text{ s} \pm 0.7 \text{ SD}$, $n = 10$) and frequent; approximately 518 copulations/clutch, among the most numerous reported for birds. High copulation frequency may be an adaptation to help ensure paternity, because male is often away from female when foraging during egg laying. Only one case of extra-pair fertilization reported (Gavin et al. in press). Female solicits copulations by facing away from male with drooped wings and flared tail-coverts. Male, wings drooped and tail-coverts flared, drops from a branch to gain momentum, then swoops upward and mounts her back. Both birds usually call while mating. Two major peaks in copulation frequency, one 30–40 d before laying, the other immediately before and during egg laying. Copulations most frequent in the morning when egg laying occurs; minor activity peak in afternoon. Copulation rate not related to prey delivery rate.

DURATION AND MAINTENANCE OF PAIR BOND. Few data; probably variable. In California, mates retained in 18 of 25 instances when mates were identified in consecutive years (Detrich and Woodbridge 1994).

Mate retention similar for both sexes. One male bred with 3 different females during a 6-yr period; 1 female was present in 3 nonconsecutive years. In a 6-yr (1991–1996) mark-recapture study of 107 pairs of nesting goshawks on the Kaibab Plateau, AZ, both mate and territory fidelity were high (R. T. Reynolds and S. M. Joy unpubl. data). Mate retention was 91.3 % (21 of 23 instances in which both pair members were trapped in subsequent years) and 77.8% for females (21 of 27 instances). Only one case of divorce (both hawks confirmed alive in subsequent years). Two males and five females changed territories; none retained mates after move. Annual replacement rate of breeding hawks on territories was 42% for males and 25% for females. However, turnover rate may be high for some populations. In California, 30% of territories ($n = 27$) were occupied by new females the year following marking, and 23% were occupied by new males (Detrich and Woodbridge 1994).

SOCIAL AND INTERSPECIFIC BEHAVIOR

Degree of sociality. Solitary outside the breeding season. Pair members winter separately (JRS). After fledging, siblings of both sexes remain together as cohesive group near the nest until dispersal (Reynolds and Wight 1978, Kenward et al. 1993b).

Play. Young birds appear to play by "attacking" leaves, sticks, pebbles, and perches (Schnell 1958).

Nonpredatory interspecific interactions. Few data. Associates with other raptors during migration, but not considered social. Mobbed by small birds on occasion. Interactions may occur when nest site is occupied by another raptor.

PREDATION

Will attack Red-tailed Hawks (*Buteo jamaicensis*; Crannell and DeStefano 1992), Short-eared Owls (*Asio flammeus*; Lindberg 1977), and Great Horned Owls struck when near nests. In Germany, territories defended against con- and interspecifics throughout the year, including Common Buzzards (*Buteo buteo*; Kostrzewa 1991). Raptors killed by Goshawks include Long-eared Owls (*Asio otus*), Tawny Owls (*Strix aluco*), nestling Honey Buzzards (*Pernis apivorus*), nestling and adult Common Buzzards, nestling and adult Sparrowhawks (*Accipiter nisus*), other Goshawks (Kostrzewa 1991), and Red-tailed Hawks (Reynolds et al. 1994). See also Demography and Populations: causes of mortality, below.

BREEDING

PHENOLOGY

Pair formation and nest building. Few data. Pairs usually return to nesting territory by Mar (Zirrer 1947, Beebe 1974, Reynolds and Wight 1978) or early Apr (McGowan 1975), some as early as Feb (Lee 1981,

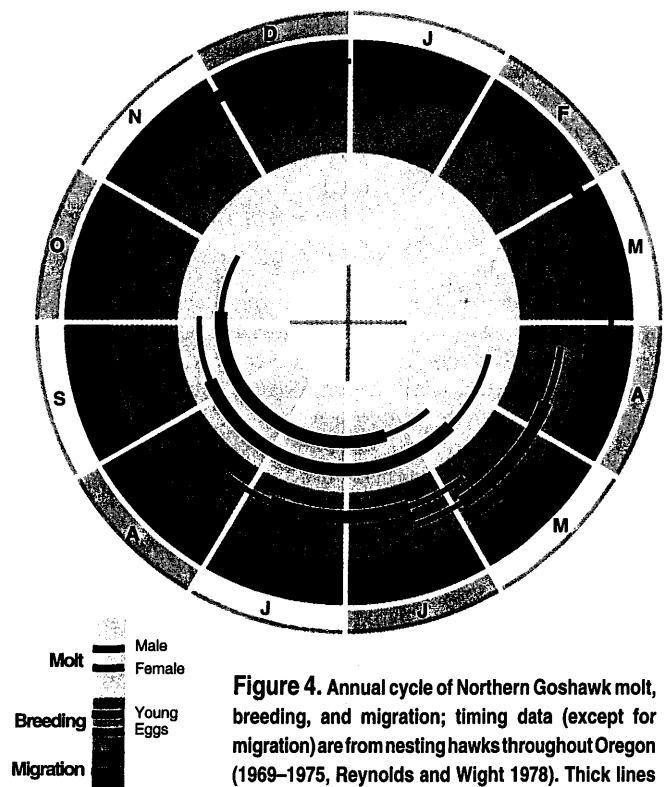


Figure 4. Annual cycle of Northern Goshawk molt, breeding, and migration; timing data (except for migration) are from nesting hawks throughout Oregon (1969–1975, Reynolds and Wight 1978). Thick lines show peak activity; thin lines, off-peak.

Speiser and Bosakowski 1991; Fig. 4). Some pairs may remain near nests year-round (Doyle and Smith 1994, Reynolds et al. 1994). In Wyoming, migratory adults equipped with transmitters returned to nest areas between 23 Mar and 12 Apr (Squires and Ruggiero 1995). Nest construction may begin soon after birds return to territories and may commence while snow is still present on nest bowl (McGowan 1975).

Only brood per season. Eggs usually laid late Apr to early May in Oregon (Bull and Hohmann 1994, DeStefano et al. 1994) and Arizona (Reynolds et al. 1994); early May in Nevada (Younk and Bechard 1994) and Alaska (McGowan 1975). In New York and New Jersey, mid to late Apr (mean = 23 Apr, $n = 20$ nests; Speiser and Bosakowski 1991). Cold, wet springs may delay incubation (Younk and Bechard 1994), likewise high elevation (Henny et al. 1985); but see McGowan (1975), Reynolds and Wight (1978).

NEST SITE

Selection. Few data. Female observed repairing nests early in season (Schnell 1958), so female may select nest site.

Site characteristics. Nests built in either coniferous or deciduous trees, depending on availability (Bent 1937, Reynolds et al. 1982). Deciduous trees often used in midwestern (Apfelbaum and Seelbach 1983) and eastern U.S. (Speiser and Bosakowski 1987). Deciduous trees used for nesting include beech, maple, birch,

aspen, and oak. In eastern forests, black birch (*Betula lenta*) and American beech (*Fagus grandifolia*) preferred, eastern hemlock (*Tsuga canadensis*) avoided (Speiser and Bosakowski 1987). Western Goshawk populations typically nest in conifers (Reynolds et al. 1982, Moore and Henny 1983, Squires and Ruggiero 1996); for example, ponderosa pine, Douglas fir, white fir (*Abies concolor*), California red fir (*Abies magnifica*), western larch (*Larix occidentalis*), western hemlock (*Tsuga heterophylla*), and lodgepole pine (*Pinus contorta*). Ponderosa pine used extensively in the Black Hills, SD (Erickson 1987), and in the Southwest (Crocker-Bedford and Chaney 1988, Reynolds et al. 1992). Deciduous trees, especially aspen, also used by western populations (Doyle and Smith 1994, Younk and Bechard 1994, Squires and Ruggiero 1996). In Alaska, paper birch (*Betula papyrifera*) used more often than aspen because of branching structure (McGowan 1975).

Typically nests in the largest trees of the nest stand (Reynolds et al. 1982, Hargis et al. 1994, Squires and Ruggiero 1996). Nests usually constructed in lower one-third of nest trees or just below the forest canopy (Reynolds et al. 1982, Speiser and Bosakowski 1987). In Alaska, nests were placed in the middle to upper canopy due to the branching pattern of paper birch, the most used nest tree for this population (McGowan 1975). Nest height significantly correlated with nest-tree height ($r = 0.86$, Kennedy 1988); thus, nest heights vary according to tree species and regional tree-height characteristics. Nest heights from select populations include 9 m (range 4.5–16.2 m, $n = 41$), Alaska (McGowan 1975); 16.8 m (range 13.4–23.8 m, $n = 13$), California (Saunders 1982); 16.9 m \pm 4.5 SD, New Mexico (Kennedy 1988); 16.2 m \pm 5.5 SD (range 4.6–27.4 m, $n = 62$), Oregon (Reynolds et al. 1982); 11.9 m \pm 0.4 SE (range 5.1–15.8, $n = 39$), Wyoming (Squires and Ruggiero 1996); and 7.4 m \pm 0.7 SE ($n = 10$) in spruce, 5.8 m \pm 0.4 SE ($n = 6$) in aspen, Yukon Territory (Doyle and Smith 1994). Size and structure of nest trees may be more important than species for most populations.

NEST

Construction process. Few observations of nest building. Female begins repairing old nests (or builds new structure) during courtship (Zirrer 1947). Gathers sticks from forest floor or breaks them from trees. Deliberate when selecting sticks, at times taking >5 min making a choice. Sticks carried in the beak; nest building in the morning lasts about 1 h. Additional nesting material added throughout incubation. Male occasionally assists in nest building (Schnell 1958, Lee 1981). Nests are constructed from material close at hand (Anonymous 1989).

Greenery, usually conifer sprigs, are placed by female on nest throughout nestling stage (Schnell 1958). Female pulls at the base of a live sprig, breaking it off,

using a technique similar to tearing prey. Sprigs then dropped on the nest, but usually not incorporated into the structure.

Structure and composition matter. Nest constructed of thin sticks (<2.5 cm diameter); "bowl" lined with tree bark and greenery. Trees with forked (deciduous) or whorled (conifer) branching generally used. Nests typically built on large horizontal limbs against the trunk, or occasionally on large limbs away from the bole (Saunders 1982). In eastern forests, most nests constructed in primary crotches; remainder in either secondary crotches or limb axils (Speiser and Bosakowski 1989). Because these preferred branching structures (triple or quadruple crotch) are uncommon in eastern forests, the presence of nests in such sites suggests that Goshawks actively select this characteristic when choosing nest trees. In the west, similar branching configurations in aspens are often used (JRS). Nests sometimes built on mistletoe clumps (Shuster 1980, Reynolds et al. 1982) or rarely in dead trees. Shuster (1980) reported that Goshawks deserted nest trees ($n = 3$) that died of beetle infestation, but there are instances where beetle-killed trees have been used as nest trees for several seasons.

Dimensions. In Oregon, nests ($n = 12$) averaged 94 cm \pm 18.5 SD in length, 66 cm \pm 20.3 SD in width; depression inside nest averaged 24 cm \pm 7.0 SD in length, 21 cm \pm 4.0 SD in width, and 8 cm \pm 7.6 SD in depth (Bull and Hohmann 1994). In Alaska, nests averaged 88.0 cm in length and 50.0 cm in width (McGowan 1975). In New York, nests ($n = 12$) averaged 90–120 cm in diameter and 60 cm in height (Allen 1978).

Microclimate. In Oregon (Moore and Henny 1983) and Wyoming (Squires and Ruggiero 1996), nests typically have southerly exposures relative to the nest-tree bole. Importance of increased insolation to incubating females is unknown.

Maintenance or reuse of nests, alternate nests. Maintains 1 to 8 alternate nests within a nest area. One nest may be used in sequential years, but often an alternate is selected. Importance of alternate nests is unknown; nest switching may reduce exposure to disease and parasites. In California, mean distance between alternate nests was 273 m \pm 68.6 SE (range 30–2,066 m, $n = 65$ nests; Woodbridge and Detrich 1994). In Oregon, alternate nests were 15–150 m apart, most 60–90 m apart (Reynolds and Wight 1978). In Arizona, average distance moved from 1991 nests to 1992 alternate nests was 266 m \pm 157 SD (range 100–635 m, $n = 17$; Reynolds et al. 1994).

EGGS

Shape. Slightly elongate elliptical (Palmer 1988); oval (Cramp and Simmons 1980).

Size. Average egg 57.76 mm \pm 2.05 SD in length, 44.73 \pm 1.67 SD in breadth (1 egg from each of 20 clutches, Palmer 1988); 59.2 mm \times 45.1 SD ($n = 50$; Bent

1937); 59 × 45 mm (51–65 × 41–49, $n = 150$, *A. g. gentilis*; Schönwetter (1967, cited in Cramp and Simons 1980). In Great Britain, an egg that was larger (62.5 mm × 49.6 mm) than 400 other eggs measured in the same area contained twin embryos (Petty and Anderson 1989).

Mass. Approximately 59 g, or 5.2% of female mass (Johnsgard 1990). In Great Britain, 63.0 g ± 3.1 SD ($n = 3$, Petty and Anderson 1989).

Color. Bluish white becoming dirty white as they fade and become stained. Usually without markings, but may be slightly blotched (Abbott 1941).

Surface texture. Slightly rough. A silky gloss finish disappears after 1–2 d (Anonymous 1990).

Eggshell thickness. In nw. Europe, 0.43 mm (95% CI 0.01, $n = 78$) 1877–1946 (pre-DDT), 0.40 mm (95% CI 0.01, $n = 39$) 1948–1961 (post-DDT; Anderson and Hickey 1974); represents a 6% decrease in shell thickness. In California, 0.410 mm (95% CI 0.025, $n = 3$) pre-1946, 0.404 mm (95% CI 0.027, $n = 9$) 1947–1964 (Anderson and Hickey 1972); represents a 1% decrease in shell thickness.

Clutch size. See Demography and Populations: measures of breeding activity.

Egg laying. Laying interval 2–3 d (Beebe 1974, Cramp and Simons 1980). A clutch of 4 eggs may take 8–9 d to complete, a clutch of 5 may take 11 d (Anonymous 1990). In Denmark, eggs are laid early in the morning (05:28 ± 9 min [SD], $n = 4$); male and female often copulate after an egg is laid (Møller 1987). Replacement clutches laid 15–30 d following egg loss (Cramp and Simons 1980), but they appear to be fairly uncommon. In Britain, despite the large number of failed nesting attempts ($n = 76$ calculated from presented data), only 3 replacement clutches observed (Marquiss and Newton 1982). In Oregon, a bird that failed 24 Apr completed a second clutch on 15 May (Henny et al. 1985). Zirr (1947) describes repeated reneesting attempts following human disturbance.

INCUBATION

Onset of broodiness and incubation in relation to laying. In n. Canada, incubation is reported to begin with the first egg (Beebe 1974). Captive breeders found that incubation begins from second egg; females flushed from partial clutches of 2 eggs or warm eggs support this observation (Anonymous 1990).

Incubation patch. One brood patch, female only.

Incubation period. 28–30 d (Beebe 1974), 35–38 d (Cramp and Simons 1980), 30–32 d (Reynolds and Wight 1978), approximately 32 d (Reynolds and Meslow 1984). 37 d ± 2 SE from second egg to hatching of first chick; 30 d ± 2 SE from final egg to hatching first chick (Anonymous 1990). Some variation attributed to prolonged pipping (Palmer 1988).

Parental behavior. Incubation primarily by female (Zirr 1947); male may assist for short periods, especially during early incubation when female eats

(Lee 1981, P. Kennedy pers. comm.). Females remain on eggs up to 244 min continuously; breaks are short, not >10 min (Allen 1978).

HATCHING

Asynchronous, but not completely, because hatching a complete clutch may take only 2–3 d, sometimes less (Cramp and Simmons 1980). Pipping of each egg takes up to 50 h; egg shells may be carried away from nest; at times found under plucking perches (Palmer 1988). No data concerning mean period between hatchings.

YOUNG BIRDS

Condition at hatching. Semialtricial and nidicolous. Recent hatchlings are warmed and fed by adult. First down short, white, tinged gray above; second down, also white but thicker, begins development at 7 d, completed by 16 d (Cramp and Simmons 1980). Boal (1994a) reported nestlings totally white in first natal down until 14–17 d, after which the gray second natal down and flight pin feathers begin to appear. Length approximately 13 cm at 4–7 d. Bare parts mostly white to very pale yellow.

Growth and development. Based on Boal 1994a and Schnell 1958. Weight gain slow during first 2 wk, followed by rapid growth from 20 to 50 d.

4–7 DAYS POSTHATCHING. Nestlings covered with white down and remain prostrate, usually out of sight in nest cup; move with scooting motions; able to excrete over nest rim with dime-sized excrement visible on nest tree and nest structure but not on ground; female continuously broods, especially at night, and usually remains motionless rather than defending nest when approached.

9–12 DAYS POSTHATCHING. Nestlings 15–18 cm long and covered with white down; usually laying in nest cup out of view; move with scooting motions, usually to feed or defecate; good head coordination when feeding but generally weak; excretes with greater power, excrement present on ground; female usually present to brood young, especially during cool mornings and at night; female actively defends nest when approached.

14–17 DAYS POSTHATCHING. Nestlings approximately 20–23 cm long and have molted into second natal down that is gray with a woolly appearance; auricular area downy; pin-feathers encased in sheathing visible in primaries, secondaries, and tail; some feathers may have erupted 1 cm; walks on tarso-metatarsus while extending wings for balance and may stand for brief moments; aware of objects away from nest.

19–22 DAYS POSTHATCHING. Auricular area small feathered patch; primaries, secondaries, and tail erupting from sheaths and contrast with body down; greater-coverts, uppertail-coverts, and scapular feathers starting to erupt; ventral feather track forming pin-feathers under down; walks on feet without using

wings for balance and can stand for longer periods and preen; wings frequently flapped for 3–5 s; attempts to rip bites from delivered prey.

24–26 DAYS POSTHATCHING. Aricular area feathered; head and neck downy, but sheathed feathers below down; scapular feathers and wing-coverts visible; feathers on ventral tracts and under tail-coverts erupt; stands on nest rim and observes surroundings; preens and wing flaps frequently; stretches legs and makes fists with talons; grabs twigs with feet; begins feeding itself if skin of prey is broken by adult; female in nest area but only broods young at night during cold, wet weather.

28–30 DAYS POSTHATCHING. Dark feathers along nape but crown downy; upperwing and back feathered; breast feathering erupting from ventral tracts but middle breast and belly downy; uppertail- and undertail-coverts and legs mostly downy but a few feathers may appear; preens often and begins Stabbing Reaction with feet at twigs in nest; begins tearing own bites from prey; sleeps standing; female rarely present at nest but present in nest area.

32–34 DAYS POSTHATCHING. Feathers emerge on crown and begin to erupt at corner of mouth; back and dorsal side of wings 90% feathered; breast becoming feathered but still downy in center and belly; undertail-coverts feathered and feathers erupting on thighs; underwing downy; tail approximately two-thirds adult length; begins fighting over food and can readily feed itself; beats wings vigorously while hopping or running across nest, can momentarily lift from nest; may engage in nest-building activities; may start "branching" (moving out along branches, away from nest) at 34–35 d.

36–38 DAYS POSTHATCHING. Body approximately 90% feathered, but down remains along side of neck; in thighs, and in underwing-coverts; head mostly feathered; tail approximately 3/4 full length; nestlings branching; some males may leave nest tree; nestlings fight aggressively over food but still accept being fed by adult; may beg for food for long periods.

GREATER THAN 40 DAYS POSTHATCHING. Appear fully feathered, except down persists along underwing-coverts; tail slightly shorter than adult; males fledged, females usually fledge by 42 d; fledglings beg for food throughout nest stand; at approximately 45 d, adults provide food away from nest.

PARENTAL CARE

Brooding. Mostly by female, but male occasionally broods young (Lee 1981). Female broods almost continually from hatch to 9–14 d (Schnell 1958, Boal 1994a). Brooding at night ceases by 24 d of age except during wet, cold weather (Boal 1994a). Females brooding young may raise slightly, allowing the nestling to move more freely. She may continue brooding without changing positions for up to 3 h. After hatch, she mainly broods and feeds young,

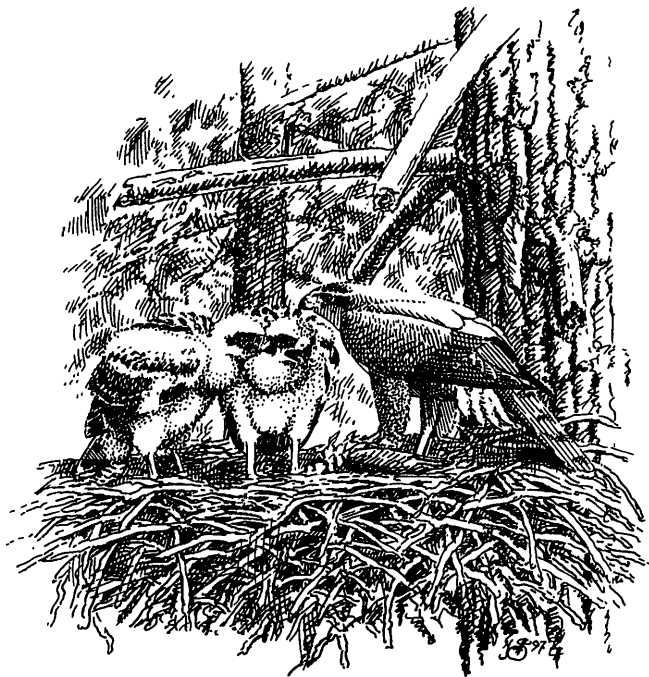


Figure 5. Northern Goshawk at its nest with young. Drawing by N. John Schmitt.

excavates the nest bowl, decorates nest with sprigs, and defends nest site.

Feeding. Figure 5. Female provisioned almost exclusively by male from courtship through early-nestling stage. Male delivers prey to mate at a roughly constant rate throughout this period (Møller 1987). Some females begin hunting during the late-nestling period (Palmer 1988); others depend on the male until fledging (Younk and Bechard 1994). Females will kill prey that pass beneath their nests. See Schnell (1958) for description of a female hunting ducklings from her nest. If male delivers prey while female is gone from the nest stand, he will deliver prey directly to nest and occasionally feeds nestlings (Allen 1978, Zachel 1985). In Alaska, 2 females provided 12.1% and 8.8% of food delivered to nest during nestling period (11–28 d; Zachel 1985). Prey were delivered by females even though males had already delivered prey to nest. In California, male provided 85% of food items, female 15% (Schnell 1958). Females from other populations may not hunt until nestlings fledge (Younk and Bechard 1994); degree to which female forages may relate to male's prey delivery rate.

Female generally feeds nestlings until they are approximately 25 d of age (Schnell 1958, Lee 1981). When male transfers prey, female usually waits for the male to leave before eating (Schnell 1958); but see (Boal 1994b). Male apparently stimulated to leave nest area by sight of female or by her Dismissal call. Female holds prey with inner toes as she tears small pieces with beak; piece is offered to nestlings who strike at adult's beak. Smallest nestlings may receive less food than larger siblings (Lee 1980). In California, feedings

averaged 11.5 min in length (range 15 s–61 min, $n = 79$; Schnell 1958); in New York, feedings for 2 nests averaged 4.4 min (range 2–7 min) and 5.6 min (range 30 s–20 min; Allen 1978).

Prey delivered throughout the day one item at a time, but peak delivery periods include early morning (06:00–07:00; Schnell 1958, JRS), midmorning, (Allen 1978), and late afternoon and evening (16:00–20:00). Prey delivery rate and timing varies according to brood size, stage of nestling development, and prey type, but these relationships have not been studied. A pair supporting 3 nestlings brought 34.8 kg of prey during the first 53 d after hatch, or approximately 11.5 kg/nestling (Zachel 1985). Two nestlings consumed an estimated 13 kg during 49 d of development (Schnell 1958). Prey delivery rates reported from Arizona, 0.25 items/h ($n = 381$ deliveries; Boal and Mannan 1994); Nevada, 0.31 items/h ($n = 51$ deliveries; Younk and Bechard 1994); and California, 3.9 prey deliveries/d ($n = 75$; Schnell 1958). Delivery rates expressed as items/h have limited interpretation, given variability of prey mass.

Nest sanitation. Nestlings defecate over nest rim by 4 d (see Young Birds). Uneaten portions of prey removed when nestlings are small (Allen 1978); after approximately 30 d, remains are left in nest until finished (Zachel 1985). Few data regarding invertebrates in nest other than observations of flies and dermestid beetles associated with prey remains.

Parental carrying of young. Not reported.

COOPERATIVE BREEDING

Not reported.

BROOD PARASITISM

Not reported.

FLEDGLING STAGE

Departure from nest. Nestlings move to nearby branches at 34–35 d of age. First flights from nest tree at 35–36 d (males), 40–42 d (females; Cramp and Simmons 1980, Boal 1994a). European males flew from the nest tree at 44 ± 0.58 SE ($n = 34$), females at 46 ± 0.85 SE ($n = 33$), but fledglings remained within 300 m of nest for about 25 d, until flight-feathers hardened (Kenward et al. 1993a, b). Age of independence from hatching to departure approximately 70 d (Cramp and Simmons 1980). Dispersal is often abrupt (Kenward et al. 1993a). Approximately 90% of fledglings disperse from nest area between 65 and 90 d of age, and 98% by 95 d; females disperse significantly later than males.

Recent fledglings depend on parents for food while their feathers harden and they learn to hunt. Adults may continue feeding less developed young in the nest in addition to feeding fledged nestlings (Lee 1980). Postfledgling movements around nest area gradually increase as they gain independence (Kennedy et al.

1994). Adults continue feeding fledglings but are intercepted away from nest as they approach with prey. In New Mexico, the mean (SD) distance from the nest at weekly intervals after first flights were (Kennedy et al. 1994) week 1, 11.8 m (32.2 m); week 2, 47.4 m (147 m); week 3, 50.4 m (93.7 m); week 4, 164.6 m (101.8 m); week 5, 302.0 m (443.3 m); week 6, 547.7 m (655.5 m); week 7, 1,330.6 m (2,402.7 m); and week 8, 1,955.6 m (1,858.5 m); maximum distance 8.8 km. On the Kaibab Plateau, AZ, dispersal from nest areas begins in mid-Aug and is completed by late Aug (Reynolds et al. 1994).

Kenward et al. (1993a) never observed young capture prey during the postnestling period (52 h observation, 8 young). In addition, trapping attempts before dispersal with live pigeons captured adults but not young. However, young readily captured live bait after dispersal, an observation suggesting that they probably disperse after acquiring hunting skills; delayed departure when birds are supplementarily fed suggests that early dispersal may be in response to food shortages (Kenward et al. 1993a).

Association with parents or other young. Siblings of both sexes continue to associate in cohesive units until flight-feathers harden; primary feathers and rectrices of females harden 62–66 d, males slightly sooner (Kenward et al. 1993a). Kenward et al. (1993b) found that females maintained closer groupings than males; males were as likely to associate with other males as with females; apparently, males moves further from the nest earlier because they were less able to kill adult rabbits compared to females.

Ability to get around, feed, and care for self. Young hawks ($n = 3$) can kill prey within 2 d of dispersal from nest area (Kenward et al. 1993b). Dispersing young will associate with broods of neighboring nests. On the Baltic island of Gotland, Sweden, nest switching following fledging was frequent, with young moving an average of 13 km to switch nests; 23% of nests ($n = 77$) received visiting young; visiting young not attacked by residents (Kenward et al. 1993b). Residents never observed feeding visitors but probably do so, given the length of time young remain in neighboring territories. Nest switching may be in response to lower food availability at natal territory.

IMMATURE STAGE

No information.

DEMOGRAPHY AND POPULATIONS

MEASURES OF BREEDING ACTIVITY

Age of first breeding. On the basis of plumage (see Appearance: molts and plumages), nesting bird can be classified as subadult (1–2 yr old, Juvenal plumage), young adult (2–3 yr old, retaining some Juvenal plumage), and adult (all adult plumage). Females

Table 3. Reproductive performance of Northern Goshawk populations in North America. Data shown as mean \pm SD (*n*). Asterisk indicates SE, instead of SD.

Location	Year	Fledglings per active nest ¹	Fledglings per successful nest ²	Nest success (%)	Study
Alaska	1971–1973	2.0 (33)	2.7 (33)		McGowan 1975
Arizona	1991	2.0 \pm 0.77 (36)	2.2 \pm 0.61 (34)	94 ³	Reynolds et al. 1994
Arizona	1992	1.8 \pm 1.05 (59)	2.2 \pm 0.72 (49)	83 ³	Reynolds et al. 1994
Arizona	1990–1992	1.9 \pm 1.0 (6–8)	2.2 \pm 0.7		Boal and Mannan 1994
California	1981–1983	1.7 (127)		91	Bloom et al. 1986
California	1987–1990	1.39 (23) ³	1.78 (18) ³	82.5 (30) ³	Austin 1993
New Mexico	1984–1988	0.94 (16)	2.14 (16)	44	Kennedy 1989
New York/ New Jersey	1977–1990	1.4 (36)		80	Speiser 1992
Oregon	1992	1.2 (12)	1.4 (10)	83	Bull and Hohmann 1994
Oregon	1969–1974	1.7 (48)		90.4	Reynolds and Wight 1978
Yukon	1989		2.0 \pm 0.35* (3)		Doyle and Smith 1994
Yukon	1990		3.9 \pm 0.37* (8)		Doyle and Smith 1994
Yukon	1991		2.3 \pm 0.25* (7)		Doyle and Smith 1994
Yukon	1992		0 (1)		Doyle and Smith 1994

¹Nests in which eggs were laid.²Nests in which young fledged.³Calculated from presented data.⁴6 of 9 failures due to human disturbance.

occasionally nest as subadults and young adults. Hoglund (1964) examined testicular development of 10 subadult males and found the size was variable and only 1 contained viable sperm. However, Glutz von Blotheim (1971, cited in Reynolds and Wight 1978) reported 2 of 30 nesting males in Juvenal plumage.

Proportion of young nesting females varies among populations; high frequency of nesting subadults in increasing populations and low frequency in stable populations (Reynolds and Wight 1978). In New York and New Jersey, only 2 females ($n=35$ nesting attempts) were in immature plumage and all males ($n=18$) were in adult plumage (Speiser and Bosakowski 1991). In Oregon, all females were in adult plumage ($n=70$; Reynolds and Wight 1978); a more recent Oregon study found 4.3% ($n=46$) of females in Juvenal plumage (Henny et al. 1985). In Nevada, 50% of females ($n=22$) were in young adult plumage and none in Juvenal; only 1 male was estimated <3 yr old (Younk and Bechard 1994). In Alaska, subadult females occupied 33% of 7 active nests, which was the only year subadults nested (McGowan 1975).

Clutch. Usually 1 clutch/yr. Clutch size usually 2–4, rarely 1 or 5 eggs. For North America, mean = 2.7 eggs \pm 0.88 SD ($n=44$; Apfelbaum and Seelbach 1983); in Oregon, 3.2 \pm 0.45 SD ($n=5$; Reynolds and Wight 1978); in Alaska, 3.2 (range 1–4, $n=33$; McGowan 1975); in Nova Scotia ($n=47$), 34% of nests contained 2 eggs; 49%, 3; and 17%, 4 (Tufts 1961). In Great Britain, average 4.0 \pm 0.11 SE (range 2–5, $n=47$); of these clutches, 2% contained 2 eggs; 21%, 3; 55%, 4; and 21%, 5 (Anonymous 1990).

Annual and lifetime reproductive success. Lifetime reproductive success unknown. Difficult to compare reproductive success across studies because of different methods and terminology. See Table 3 for measures of annual reproductive performance. Yearly nest occupancy is difficult to determine because of secretive nature of adults and their sometimes extensive movements to alternate nests. Yearly occupancy rates highly variable, possibly in response to fluctuating prey densities and severe weather conditions. In s. Cascades of California, nest stands in territories with ≥ 5 yr of monitoring ($n=71$) were occupied an average 46% \pm 6 SE of time (Woodbridge and Detrich 1994). In Alaska, occupancy varied from 6% (1974) to 56% (1972, $n=16$; McGowan 1975). In Arizona, 92% of nests occupied in 1991 ($n=37$) were reoccupied in 1992 (Reynolds et al. 1994); in Oregon, 40% were reoccupied ($n=63$ sites, Reynolds and Wight 1978). In New York and New Jersey, sites were occupied an average of 3.8 yr ($n=18$; Speiser and Bosakowski 1991).

Percentage of active nests (nesting attempts where eggs were laid) are variable. In California (1981–1983), the percentage of active nests ($n=114$ nest territories) ranged from 49% in 1982 to 84% in 1981; in the Sierra Nevada and White Mtns., CA, where winters are harsh, percentage of active nests varied from 86% in 1981 to 27% in 1983 (Bloom et al. 1986). Annual proportion of territorial pairs ($n=36$ –107 territories) laying eggs on the Kaibab Plateau, AZ, varied from 22–86% (R. T. Reynolds and S. M. Joy unpubl. data). Few studies estimate hatching success. In Oregon, hatching success 81.2% ($n=5$ nests; Reynolds and

Wight 1978). In Britain, 63.4% of eggs ($n = 186$ eggs) survived to produce young that fledged; mean brood size at hatching was 3.00 ± 0.17 SE ($n = 45$) and 2.76 ± 0.16 SE at fledging (Anonymous 1990). In Arizona, the modal brood size was 2, with 1 fledgling produced at 16% of nests ($n = 13$), 2 at 53% ($n = 44$), and 3 at 31% ($n = 26$; Reynolds et al. 1994). In Sweden, average brood size (approximately 3 wk old) of 2.7 ($n = 15$; Widén 1985).

Few data concerning nonbreeders; only crude measures available. In Sweden, 4 of 12 radioed Goshawks (sexes not specified) failed to breed, an observation suggesting approximately one-third of sedentary population were nonbreeders (Widén 1985). In Finland, the proportion of nonbreeding pairs increased from 35% to 52% in an apparent response to declining grouse populations (Lindén and Wikman 1983). Also in Finland from 1977 to 1982, the proportion of nonbreeders, usually single birds, decorating nests varied between 0% (1979) and 57% (1982; Forsman and Solonen 1984).

Number of young per successful clutch and pair. Highly variable. Nest success (percentage of active nests that fledged young) is usually between 80% and 94%; most populations produce from 2.0 to 2.8 fledglings/successful nest (Table 3). In Arizona ($n = 98$ nests), 85% of nests successfully fledged young, 3% either did not lay eggs or clutches were lost during early incubation, 6% clutches were lost during incubation, and 6% failed during nestling period (Reynolds et al. 1994). In Yukon Territory, the number of fledglings/successful nest varied from 0 (1992) to 3.9 (1990; Doyle and Smith 1994).

Mortality usually low during the nestling stage; believed to be highest during first year after dispersal. Unsuccessful nests usually failed early in the breeding season, before or soon after laying (Widén 1985). Pairs rarely fail after chicks are 3 wk old. In New Mexico, nestling survival varied from 100% (6 nests) at control nests (pairs not receiving supplemental feeding) in 1992 to 37% at 8 control nests in 1993 (Ward and Kennedy 1996). In Britain, 22.6% of eggs ($n = 186$) failed during egg stage, 8.1% at small-chick stage, and 5.9% during prefledging stage (Anonymous 1990). In Alaska, nestling survival estimated at 98% (1971–1973, $n = 33$; McGowan 1975). On the Baltic island of Gotland, 3% ($n = 73$) of radio-tagged males and 8% of females that fledged died before dispersal (Kenward et al. 1993b).

Siblicide and cannibalism occurs, especially during periods of food deprivation (Schnell 1958, Zachel 1985, Boal and Bacorn 1994). Older nestlings may attack younger birds with aggressive strikes to head and eyes. Kenward et al. (1993b) documented 2 instances of 10-d-old chicks found with head injuries consistent with pecking by siblings and another bird with probable claw wound in cranium. At hatch, sex ratio was 1:1 but females predominated in broods that lost most

offspring, an outcome suggesting siblicidal interactions favor the larger females.

Number of broods normally reared per season. One.

Factors affecting productivity. Productivity varies between years on same study areas, and among landscapes within a limited geographic area (DeStefano et al. 1994; Table 3). Prey availability strongly affects occupancy (McGowan 1975) and productivity (Lindén and Wikman 1983, Doyle and Smith 1994). See Population Regulation, below.

Cold springs and exposure to cold and rain can cause egg (Hoglund 1964, JRS) and chick mortality (Zachel 1985). In Germany (Kostrzewa and Kostrzewa 1990), spring rainfall and temperature had little effect on the density of territorial pairs, but the number of pairs actually laying eggs was negatively correlated with Mar and Mar–Apr rainfall; fledglings per successful nest was positively correlated with Apr–May temperature, May temperature, and negatively related to number of rainy days in May. Chicks had retarded development during cold, wet springs. In Britain, increased altitude was correlated with delayed mean laying date, increased number of addled eggs, and smaller brood sizes (Marquiss and Newton 1982). In Germany, winter weather did not affect density, percentage of laying, and breeding success, but winter conditions were relatively warm (mean = 3.0°C) and dry (Kostrzewa and Kostrzewa 1991).

Age of female also may affect productivity. In Arizona, young-adult to adult pairings produced fewer fledglings/active site (1.1 fledglings \pm D 0.9 SD, $n = 9$) than adult/adult pairings (2.3 fledglings \pm 0.8 SD, $n = 21$; Reynolds et al. 1994). Young-adult females and young-adult males were similarly productive. In Nevada, however, young females were as productive as older birds (2.54 vs. 3.0 young/nest, $n = 11$ Basic I plumage females), but fledged young at a later date (Younk and Bechard 1994). Also see Conservation and Management: effects of human activity, below.

LIFE SPAN AND SURVIVORSHIP

Few data, most from European studies; survival estimates based on band recoveries may be biased as a result of differing vulnerability among age and sex classes to capture (trapping and shooting). Average survival based on band return data is 10.7 mo ($n = 120$; Keran 1981). Maximum life span of wild birds is at least 11 yr (Fowler 1985). Estimated mortality rates of Finnish and Swedish birds based on banding recoveries ($n = 552$, years 1950–1966), assuming a 60% reporting rate, are 66%, year 1; 33%, year 2; 19%, year 3; 19%, year 4; and 11%, following years (Haukioja and Haukioja 1970). Survivorship between banding and recovery was 287 d for birds banded in Sweden and 221 d for those in Finland (Hoglund 1964). A mark-recapture study (1991–1996) on the Kaibab Plateau, AZ, estimated annual survival of males (>1 yr-old) at 68.8% (SE = 0.07) and females (>1 yr-old) at

86.6% (SE = 0.05; R. T. Reynolds and S. M. Joy unpubl. data).

Winter survival favors birds of higher body mass; females appear to be more vulnerable to food shortage than males (Marcström and Kenward 1981b). It is unknown how changes in landscape pattern or other environmental factors affect survivorship.

DISEASE AND BODY PARASITES

Diseases. Bacterial diseases include tuberculosis (*Mycobacterium avium* infection; Lumeij et al. 1981) and erysipelas (*Erysipelas insidiosa* infection; Schröder 1981). Symptoms for tuberculosis included loss of balance, leg weakness, trembling and convulsions, necrotic lesions under tongue, necrotic masses in lung, air sacs, and base of heart and millet-size to walnut-size yellow-white foci in major organs, especially liver and spleen (Lumeij et al. 1981, Schröder 1981). *Chlamydia tsittaci* and *E. coli* caused heart failure (Ward and Kennedy 1996). Fungal disease from genus *Aspergillus* when chronic produces granulomas throughout lungs and air sacs. Of migrants captured in Minnesota, 53% ($n = 49$) had *Aspergillus* in 1992 (invasion year), but only 7% ($n = 45$) were infected in 1993 (Redig et al. 1980). Stress caused by agonistic interactions, reduced prey abundance, and migration during invasion years may increase susceptibility to *Aspergillus*.

Body parasites. Heavy infestations of ectoparasites usually occur in weakened birds; lice (*Degeeriella nisus vagrans*) occur in plumage (Keymer 1972).

Internal parasites common. In Alaska, 71% of birds ($n = 31$) had parasites (45% with cestods, 32% trematodes, 7% both, McGowan 1975). In North America, approximately 56% ($n = 36$) of birds had blood parasites that included *Leucocytozoon*, *Haemoproteus*, *Trypanosoma*, and microfilariae (Greiner et al. 1975). Other blood parasites include *Haemoproteus* spp. and *Leucocytozoon* spp. (Peirce and Cooper 1977). In Britain, trichomoniasis caused by protozoan parasite *Trichomonas gallinae* found in upper digestive tract killed 14 young from 5 broods (Cooper and Petty 1988); mortality from this parasite reduced the productivity of the population approximately 15%. *T. gallinae* can cause severe lesions, usually a stomatitis that obstructs the buccal cavity and pharynx and causes the disease known as "frounce," a disease of the crop that may be contracted by feeding on fresh pigeons; may represent a threat to some Goshawk populations (Beebe 1974), but data lacking. Sarcocystis parasites can cause encephalitis (Aguilar et al. 1991). Serves as definitive host for heteroxenous coccidians (Cerna 1984).

CAUSES OF MORTALITY

On the Baltic island of Gotland, natural mortality agents included starvation (37%), disease (7%), a combination of both (22%), and trauma (33%, including 2 birds killed by other Goshawks). Trauma-induced mortalities include shooting, trapping, injuries (Jälefors

1981), and roadkill (Keran 1981); shooting, trapping, and poisoning are especially common mortality factors for European populations. Of 11 adult recoveries in Britain, 2 were roadkills, 8 were shot, trapped, or poisoned; cause of remaining death was unknown (Marquiss and Newton 1982). For nestling mortality, see Demography and Populations: measures of breeding activity.

Exposure. Few data. See Demography and Populations: measures of breeding activity.

Predation. Few natural predators. Great Horned Owls kill adults and nestlings (Moore and Henny 1983, Rohner and Doyle 1992, Boal and Mannan 1994, Woodbridge and Detrich 1994); predation on nestlings may increase during periods of low food availability (Zachel 1985, Rohner and Doyle 1992). In Europe, Eagle Owls (*Bubo bubo*) eat nestlings between 13 and 38 d (Tella and Mañosa 1993). Owls often eat entire broods over several consecutive nights, especially when prey availability is low. Eagles kill wintering birds (Squires and Ruggiero 1995). A marten (*Martes americana*) stalked and killed a female Goshawk while perched approximately 20 cm above snow and dragged the carcass approximately 0.5 km before dismembering it under the snow (Paragi and Wholecheese 1994). Wolverines have killed 3-wk-old chicks by climbing the nest (Doyle 1995). Claw marks suggest a mammalian predator climbed a nest tree in Alaska (McGowan 1975), and one-half of nestling mortalities ($n = 12$) in New Mexico were attributed to predation (Ward and Kennedy 1996). For siblicide, see Demography and Populations: measures of breeding activity.

RANGE

Initial dispersal from natal site. Very few data. In California, 2 females of 119 banded nestlings relocated as breeders nested 16.1 and 24.2 km from natal sites (Detrich and Woodbridge 1994). A female banded in 1988 as a nestling was recaptured in 1995 as a breeding adult approximately 100 km from its natal site (B. Woodbridge pers. comm.). On the Kaibab Plateau, AZ, 3 females banded as nestlings were recaptured as breeding adults a mean of 21.5 km from natal sites, whereas 3 male nestlings were recaptured a mean of 15.9 km from its natal site (R. T. Reynolds and S. M. Joy unpubl. data). In New Mexico, a female hatched in 1984 bred at a site 6.4 km from her natal site during 1989. See Breeding: fledgling stage.

Fidelity to breeding site and winter home range. May use the same nest for consecutive years, but typically alternate between ≥ 2 nests within nest areas (Reynolds and Wight 1978). Fidelity to breeding territories is hard to determine because of difficulties in locating all alternative nest sites. Most nest sites occupied from 1 to 3 yr; some much longer. In e. U.S., nest areas were occupied for an average of 3.83 yr \pm 3.05 SD (range 1–8, $n = 35$ attempts at 20 nest areas);

a nest site in Washington was continuously occupied at least 10 yr (Speiser and Bosakowski 1991). Turnover rates of individual birds were unknown for these sites. In Britain, of 33 successive nesting attempts, only 6 (18%) reused the same nest; in 2 cases the same nest was used >3 seasons (Anonymous 1989).

In n. California, territory occupancy by the same bird averaged 1.8 yr for females ± 1.3 SD (range 1–7 yr, $n = 40$) and 1.3 yr ± 0.54 SD (range 1–3 yr, $n = 27$) for males (Detrich and Woodbridge 1994); observed mean occupancy rates probably less than actual because of difficulty in locating nests in consecutive years and observing nesting males. Males were more likely to remain in the same territory in consecutive years than females. Female movements to nesting territories in subsequent years averaged $9.8 \text{ km} \pm 2.7$ SD (range 5.5–12.9 km, $n = 4$), males $6.5 \text{ km} \pm 2.7$ SD (range 4.2–10.3 km, $n = 3$).

On the Kaibab Plateau, AZ, tenure by marked hawks averaged 1.9 yr for females (range = 1–6, $n = 36$ territories studied for 6 yr) and 1.4 yr for males (range = 1–6 yr). On an additional 27 territories studied for 5 yr on the Kaibab, tenure was 1.8 yr (range 1–5 yr) for females and 1.6 yr (range = 1–5 yr) for males (R. T. Reynolds and S. M. Joy unpubl. data). On average, between 52 and 73% of pairs move annually to nest in alternative nests within their territories (R. T. Reynolds and S. M. Joy unpubl. data). Females moved more often and moved farther from one nesting territory to another compared to males; 5 females moved an average of 5.2 km (range = 2.4–8.6 km) and 2 males moved an average 2.6 km (range = 2.0–3.5 km; R. T. Reynolds and S. M. Joy unpubl. data).

Fidelity to wintering sites unknown. Also see Breeding: nests.

Dispersal from breeding site or colony. See Breeding: parental care.

Home range. In North America during nesting, 570–3,500 ha, depending on sex and habitat characteristics. Male's home range usually larger than female's (Hargis et al. 1994, Kennedy et al. 1994); there are exceptions (Austin 1993). Home ranges, excluding nest areas, apparently not defended and may overlap adjacent pairs. Birds usually have one to several core-use areas within a home range that include nest and primary foraging sites. Core areas are approximately 32% of home range area (Kennedy et al. 1994). Shapes of home ranges vary from circular to almost linear and may be disjunct, depending on habitat configuration (e.g., Hargis et al. 1994). Use of disjunct areas increases the vegetative diversity and perhaps prey base available to foraging birds.

Comparison of home range size among studies is difficult and may not be meaningful because of differences in the methods of calculation. Average home range sizes (based on telemetry) of select populations include: Arizona, males $1,758 \text{ ha} \pm 500$ SD (range 896–2,528, $n = 11$; Bright-Smith and Mannan

1994); New Mexico, females $569 \text{ ha} \pm 473$ SD (range 95–1,292, $n = 5$), males $2,106 \text{ ha} \pm 635$ SD (range 1,698–2,837, $n = 3$; Kennedy et al. 1994); California, females $1,340 \text{ ha}$ (SD 810, $n = 7$) and 2 males 1,790 and 3,010 ha (Hargis et al. 1994); and n. California, male 2,425 ha (range 1,083–3,902, $n = 5$), female 3,774 ha (range 2,007–6,908, $n = 5$), each pair used approximately 4,765 ha (Austin 1993). In Alaska, median home ranges during nesting were 3,982 ha for males (range 728–19,407 ha) and 2,737 ha (range 273–111,407 ha) for females, but were highly variable (Titus et al. 1994).

Individuals may shift home ranges after breeding (Hargis et al. 1994, Keane and Morrison 1994). In California, females ($n = 7$) expanded home ranges after nestling stage from $520 \text{ ha} \pm 390$ SD to $1,020 \text{ ha} \pm 820$ SD; 2 males expanded their ranges from 340 to 1,620 ha and from 950 to 2,840 ha (Hargis et al. 1994). A female from this population shifted its home range 9 km after young fledged. In n. California, home ranges of males ($n = 5$, 95% minimum convex polygon) increased from 1,880 ha during nesting (Jun–15 Aug, range 1,140–2,950 ha) to 8,360 ha (range 1,340–15,400 ha) during the nonbreeding season (15 Aug 1992–Mar 1993); home ranges of females increased from 1,280 ha (range 690–3,280, $n = 5$) to 3,180 (range 1,220–4,010 ha) during the same period (Keane and Morrison 1994).

Home ranges of nonbreeders poorly understood, but may be larger than those of breeders (JRS). In Yukon Territory, a nonbreeding adult male's home range during May was 4,000 ha and that for an immature female was 2,880 ha (Doyle and Smith 1994).

Winter range. In North America, characteristics of winter home ranges unknown. In Sweden, home ranges smallest where prey densities were greatest, and largest when the home range contained the least woodland edge (Kenward and Widén 1989). Winter home ranges varied in size from 2,000 ha (range 700–4,600 ha, $n = 10$) in an area with abundant, released Red-necked Pheasants (*Phasianus colchicus*) to 5,400 ha (range 2,400–10,100, $n = 8$) in an area of low pheasant abundance (Kenward et al. 1981a). In Swedish boreal forests, winter home ranges of all birds averaged $5,700 \text{ ha} \pm 2,298$ SD ($n = 14$); both male (mean $5,100 \text{ ha} \pm 2,327$ SD, range 1,800–8,000 ha, $n = 6$) and female (mean $6,200 \text{ ha} \pm 2,321$ SD, range 3,200–92,000 ha, $n = 8$) home ranges were similar in size (Widén 1989). Low prey densities may explain large home ranges. In Germany, winter home range was estimated to be 5,000 ha on the basis of plots of kill sites (Brüll 1964).

POPULATION STATUS

Estimates of density. As top-level carnivores, density of breeding pairs is low and difficult to document because extensive nest searches are needed over large areas. How various environmental conditions such as vegetative type and landscape characteristics affect breeding densities are poorly understood. Densities are highly variable among populations (see Table 4).

Table 4. Nesting density of Northern Goshawks in North America.

Location	Year	Density, pairs/100 km ²	Forest type	Study
Alaska	1971–1974	0.3–2.4 ¹	Aspen/spruce/birch	McGowan 1975
Arizona	1995	6.8 ²	Ponderosa pine	RTR
California	1984–1992	10.7	Sierran montane, upper montane	Woodbridge and Detrich 1994
Colorado	1974	5.8	Lodgepole pine/aspen	Shuster 1976
New Mexico	1984–1988	6.4	Ponderosa pine	Kennedy 1989
Oregon	1992–1993	6–7	Mixed conifer	DeStefano et al. 1994
Oregon	1974	3.6	Ponderosa pine	Reynolds and Wight 1978
Pennsylvania	1988–1991	1.17 ³	Northern hardwood/Appalachian oak	Kimmel and Yahner 1991
Yukon Territory	1990	5	Spruce/aspen	Doyle and Smith 1994

¹Variation across years.²Estimated density based on complete counts over approximately 80% of study area.³Variation across study years.

In North America, most western populations at midlatitudes have approximately 3.6–10.7 pairs/100 km². A total of 107 nesting territories (1991–1996) were located on a 1,754 km² study area on the Kaibab Plateau, AZ. Nests of adjacent pairs were regularly spaced at a mean nearest-neighbor distance of 3.88 km (SD = 0.83). At the end of 1996 field season, about 75% of the Kaibab Plateau study area was searched. A total of 107 pairs were located. Extrapolating to the remaining 25% of the study area, using a mean territory distance of 1.88 km, estimated a total of 148 pairs on the plateau for a density of 8.4 pairs/100 km² (R. T. Reynolds and S. M. Joy unpubl. data). The estimated density in Pennsylvania (1.17 pairs/100 km²; Kimmel and Yahner 1994) suggests that eastern populations may occur at lower densities than western populations, but densities of eastern populations may increase as these populations recover (see Trends: geographic and temporal, below). Population estimates over large geographic areas are difficult to determine and represent only crude estimates. Populations at far northern latitudes may occur at lower densities than those of southwestern and western populations in North America (Table 4). However, Kenward et al. (1991), on the basis of various European studies, reported that ≥3,000 breeding pairs exist in France, Germany, and Spain, and at least 14,000 pairs exist in Scandinavia.

Trends: geographic and temporal. Poorly understood. Migration or Christmas counts are difficult to interpret because of low numbers observed and irruptive migrations (Titus and Fuller 1990); in addition, low prey availability and severe weather cause reproductive output to be highly variable, confounding interpretation of population trends. Eastern populations apparently are increasing as forests regenerate (see Distribution: historical changes). Counts of migrants in Utah, Nevada, and New Mexico suggest numbers declined approximately 4%/yr (1983–1991;

Hoffman et al. 1992). Because most birds (58%) were immatures, declines may be due to poor reproduction or decreases in numbers of breeding pairs rather than large-scale, regional declines.

Based on counts at Hawk Mountain, PA, numbers hit a low between late 1930s and early 1950s before gradually increasing through 1960s (Nagy 1977). Population trends derived from Hawk Mountain counts confounded by irruptive years (1930s, early 1970s), but generally increased during DDT period (1946–1972); numbers declined 1971–1986, but population fluctuations may not be adequately monitored by migration counts (Bednarz et al. 1990). Number of migrants has been relatively stable from 1966–1970 period through the present (1996), except for peak numbers observed during invasion years (Table 1); counts of migrants at 6 eastern hawk-count sites from 1972 to 1987 yielded inconsistent trends (Titus and Fuller 1990).

Nest survey techniques. The most efficient method for locating nests involves broadcasting taped Broadcast Alarm or Begging calls along transects (Kennedy and Stahlecker 1993, Joy et al. 1994). In Arizona, Alarm calls worked better than Food-Begging calls during both nestling and fledgling periods (Joy et al. 1994); however, in New Mexico, Food-Begging calls were better during fledgling period (Kennedy and Stahlecker 1993). Both males and females respond well to calls, but males are more likely to approach and retreat silently (Joy et al. 1994).

POPULATION REGULATION

There is limited understanding of how predation, competition, landscape alteration, or food availability regulate Goshawk populations. Food availability is believed to strongly affect population dynamics; evidence is especially strong at northern latitudes where few prey species occur. In Yukon Territory, sightings decreased as snowshoe hare populations

declined; an average of 3.9 young/successful nest ($n = 8$) were produced when hare populations were high, while all reproductive efforts failed when hare numbers were low (Doyle and Smith 1994). In Finland from 1977 through 1981, average number of young fledged/occupied site varied from 0.9 (1977) to 2.5 (1980); average clutch and brood sizes remained relatively constant as grouse populations declined (Lindén and Wikman 1983), but during this period the number of breeding pairs declined sharply. In New Mexico, nestlings had a higher survival rate (mean $90\% \pm 6$ SD, $n = 15$) at sites that were experimentally augmented with food relative to nestling survival at control nests (mean $37\% \pm 17$ SD, $n = 8$) in 1993 but not in 1992; increased time spent by females attending augmented nests during 1993 may have increased nestling survival by deterring nest predation (Ward and Kennedy 1996).

CONSERVATION AND MANAGEMENT

EFFECTS OF HUMAN ACTIVITY

Shooting and trapping. In North America, not considered an important mortality factor. Some states, like Pennsylvania, paid \$5 bounties on Goshawks in 1930s (Anonymous 1930); the effect that shooting and trapping had on populations during the 1900s is unknown. European populations were more actively persecuted in efforts to protect private game-bird farms. On the Baltic island of Gotland, 36% of mortalities of radio-tagged birds ($n = 67$) were killed by humans (Kenward et al. 1991); juveniles were more likely to be shot than adults.

Pesticides and other contaminants. In early 1970s pesticide levels in U.S. Goshawks were low (Snyder et al. 1973). Eggshell thinning has not been a problem for most populations, although California eggshells (weight and thickness index) pre-1947 (pre-DDT, $n = 23$) to 1947–1964 (DDT in use, $n = 34$) declined 8–12% (Anderson and Hickey 1972). In Illinois, wintering Goshawks during 1972–1973 invasion year contained less organochlorine and PCB residues than did other raptors (Havera and Duzan 1986). These birds were probably from nonagricultural, northern forests.

In Sweden, mercury levels in feathers, nineteenth century to 1940, were approximately 2 ppm ($n = 16$); increased to approximately 20 ppm during the 1940–1965 period as methyl mercury was applied as seed dressing (Johnels et al. 1979); dropped after 1966 to approximately 3 ppm ($n = 27$) as alkyl mercury compounds as seed dressings were banned and replaced by alkoxy-alkyl mercury compounds.

Degradation of habitat. Timber harvest is a primary threat to nesting populations (Reynolds 1989, Crocker-Bedford 1990). Each year nests are destroyed by logging operations, but impacts to nesting populations are unknown; breeding densities may be lowered or individuals may redistribute to adjacent areas. Harvest

methods that create large areas of reduced forest canopy cover (<35–40%) may be especially detrimental (Bright-Smith and Mannan 1994, Beier and Drennan 1997); some forest managers mistakenly view low forest canopies as desired conditions rather than minimum values (Arizona Game and Fish Department 1993). However, forest harvest may be compatible with Goshawk management provided that habitat needs are provided at multiple spatial scales (Reynolds et al. 1992, see Management, below). In harvest areas where overstory trees were removed but numerous mature stands were retained, birds still nested approximately two-thirds of the time ($n = 14$ yr) and produced typically 2–3 young/nest (Hargis et al. 1994). In California, nesting densities remained fairly high despite fragmentation of mature forests through timber harvest (Woodbridge and Detrich 1994); however, territories associated with large contiguous forest patches were more consistently occupied compared to highly fragmented stands. Although nesting frequently occurs in areas impacted by timber harvest, the long-term viability of these populations is unknown. In New Jersey and New York, nests were further from human habitation than expected on the basis of available habitat (Speiser and Bosakowski 1987), an observation suggesting that disturbance reduces habitat quality.

Winter habitat use is so poorly understood that potential impacts of human activities cannot be assessed.

Sensitivity to disturbance at nest and roost sites.

Timbering activities near nests can cause failure, especially during incubation (Anonymous 1989, Boal and Mannan 1994). Logging activities, such as loading and skidding, within 50–100 m of nest can cause abandonment, even with 20-d-old nestlings present (JRS). However, see Zirrer (1947) for descriptions of repeated renesting attempts despite extreme disturbance. Camping near nests has also caused failures ($n = 2$; Speiser 1992).

Research impacts. Disturbances associated with research are usually of short duration, apparently having little impact on nesting birds. Viewing nests for short periods after young have hatched does not cause desertion. Trapping adults during nesting for banding or attaching transmitters apparently does not cause abandonment. The percentage of nesting pairs with radios that successfully raised young (83%, $n = 8$, 1988–1989) was similar to those without radios (82%, $n = 10$, 1987–1990; Austin 1993).

Falconry. Impact of falconry on wild populations is unknown, but thought to be minimal. Has been trained for falconry for at least 2,000 yr; species was favored among Oriental, Middle Eastern, and North European falconers (Cooper 1981) and especially prized by Japanese falconers. Depicted in a ninth-century Bayeux Tapestry where King Harold hunted with hawk and hounds. During the eighteenth century, falconry declined and Goshawks were viewed as competitors

for game as guns became available. Since World War II, interest in falconry has increased and spread to North America. Modern-day falconers value Goshawks for their willingness to hunt a variety of prey and their aggressive dispositions. Members of the British Falconers' Club report a relatively constant annual mortality rate of 22% for captive birds ($n=216$; Kenward et al. 1981b); most birds died of infectious disease or in accidents when used for hunting. See Beebe (1976) for description of training.

MANAGEMENT

Conservation status. Prior to 1970s, not afforded special management protections. Not currently listed as Endangered or Threatened. In 1991, was designated a "Category II" species of concern by the U.S. Fish and Wildlife Service (FWS), meaning additional information was needed before final listing status was determined; Category II designations eliminated in 1996. In 1993, a petition to list the Queen Charlotte Goshawk subspecies as Endangered was submitted to the FWS. The FWS subsequently found the petition unwarranted on the basis of available data (50 CFR 17). Goshawk is included on the "Sensitive Species" lists of the U.S. Forest Service (USFS) in the Pacific Southwest (1981), Southwest (1982), Intermountain (1992), Rocky Mtns. (1993), and Alaska (1994) regions; Northern, Eastern, and Pacific Northwest regions do not list the species. Sensitive species designation requires biological evaluations to consider potential impacts of proposed management actions. Goshawks are also considered "management indicator" species on many national forests because they are potentially sensitive to habitat change.

In Canada, *A. g. atricapillus* is considered "not at risk" in all provinces on the basis of a recent evaluation; the subspecies *A. g. laingi* is considered "vulnerable" because it has a small population subject to habitat fragmentation on islands (Duncan and Kirk 1994). Considered threatened in Mexico (Estados Unidos Mexicanos 1994).

Measures proposed and taken. Management agencies usually attempt to reduce disturbance during nesting period by delineating protected areas around nest trees (Reynolds 1983). Crocker-Bedford (1990) found that, between 1985 and 1987, 66% of control nests were reoccupied at least once compared with only 12% of buffered nests. Occupancy was low in both small (1.2–2.4 ha) and large (16–200 ha) buffered nests, a result suggesting that the sizes of buffer areas were inadequate.

Reynolds et al. (1992) developed management recommendations for nesting birds in the sw. U.S. These recommendations describe desired forest conditions for nesting and foraging habitat; especially emphasized are forest conditions for supporting diverse prey populations. Recommendations prescribe habitat conditions at 3 spatial scales—nest, post-

fledgling areas and foraging areas.

Timber harvest may be used to improve nesting habitat (Reynolds et al. 1992). In some cases, harvest may be necessary to restore forest structure in damaged ecosystems. In the Rocky Mtns., mature lodgepole pine stands are often not recognized as potentially important nesting habitat in management plans; old-growth scoring procedures used by agencies may need modification so that forest structures associated with nesting habitat (often lacking structural complexity) are identified as important habitat components (Squires and Ruggiero 1996).

APPEARANCE

MOLTS AND PLUMAGES

Hatchlings. Short, white natal down at hatch; often slightly grayish on head and back (Palmer 1988). From approximately 1 wk of age to 16 d, long dense second down that is grayish dorsally and white ventrally replaces natal down.

Juvenal plumage. Juvenal plumage begins to emerge by about 17–18 d; mostly complete by 36–40 d. Also see Breeding: young birds. Juvenal plumage is retained throughout winter.

(From Johnsgard 1990, Palmer 1988). Upperparts, including wings, dark brown to brown-black, with buff white and cinnamon streaks; tail dark brown with wavy dark-brown bands with thin whitish borders forming a zigzag pattern; back- and upperwing-coverts brown with extensive tawny and white mottling. Underparts, including wing-linings, buff white with thick cinnamon to blackish brown streaks on throat. Undertail-coverts usually streaked and not fluffy. Head is brown and usually has a pale whitish superciliary stripe.

Basic I plumage. MALE. Basic I plumage attained during summer at approximately 1 yr of age, sometimes earlier. Similar to Definitive Basic plumage by second winter but browner; ventral markings coarser with more streaking and some barring. Upperwing-coverts, back, and breast may retain a few Juvenal brown feathers until following year (age 2). High degree of individual variation may lead to similarity between Basic I and Definitive Basic plumages (Palmer 1988). See Bare Parts, for changes in iris color.

FEMALE. Similar to male.

Definitive Basic plumage. Definitive Prebasic molt almost complete; may not include all secondaries (see below). Males molt late in the breeding season, possibly because they need maximum flight efficiency for providing food for the female and nestling; females molt during incubation. Primary remiges replaced from innermost (P1) outward (P10), dropping next feather in sequence as adjacent feather is partially grown (Henny et al. 1985, Reading 1990). Molt pattern of secondaries is largely dependent on molt pattern

the previous year (Reading 1990); the total number of secondaries (16 feathers) molted during a given year is variable. Rectrices molt (12 feathers) sequence is variable; usually center feathers are first to drop. Molt symmetry between sides is greatest for primaries and least in tail. Timing of molt is similar for Basic I and Definitive Basic plumages; nonbreeders may molt earlier than breeders. Arrested molts occur during times of peak energy demands.

MALE. Upperparts, including back- and upperwing-coverts, vary from dark gray, brown-gray, slate gray to bluish, becoming darker on the nape and crown; top of head dark slate to slate black; nape and side of crown have heavy white mottling so appearance is whitish rather than slate (Johnsgard 1990). Has an obvious white superciliary line. Underparts, including breast and abdomen, white to pale gray, with fine gray vermiculation and fine blackish streaks. Uppertail-coverts and rump are like back. Undertail-coverts whitish and fluffy. Tail is dark gray above and paler gray below, long and straight, with the tip slightly to moderately rounded and crossed by 3–5 broad, blackish bands, which may be indistinct or much reduced on some individuals; ventrally at least 4 dark transverse bands narrower than the lighter intervening spaces (Palmer 1988). Tail narrowly tipped with white (reduced or absent with wear). Primaries and secondaries dark gray with cream-color barring; tertials dark gray. Underwings two-toned; whitish with dark gray barring on coverts contrast with dark flight-feathers. Flight-feathers lightly barred below; 5 outermost primaries emarginated on inner webs. Underwing-coverts white with dark gray barring.

FEMALE. Similar to adult male but usually slightly more brown above and more coarsely marked with dark gray below. Females may have coarser, darker barring, and more vertical black streaking.

BARE PARTS

Bill and gape. Gray, with cere and gape greenish gray to pale yellow as juveniles; becoming black to bluish with yellow cere and gape as adults.

Iris. Iris initially greenish gray, turning pale yellow. Iris bright yellow throughout first year, progressively becoming orange during their second year. Adult iris dark red to mahogany.

Legs and feet. Tarsi and toes greenish gray to pale yellow as juveniles, becoming yellow as adults. Tarsus feathered approximately half way down in front. Claws bluish black to black.

MEASUREMENTS

See Appendix 2. Average length of *A. g. atricapillus* in North America: 56 cm (53–58.5 cm), for males; 61 cm (57.5–64 cm), females (Mueller et al. 1979). Also see Systematics: geographic variation.

PRIORITIES FOR FUTURE RESEARCH

Determining how changes in forest structure and landscape pattern affect population viability is especially important to population management. We do not know how population demographics are impacted by increased habitat fragmentation or by changes in structure at various ecological scales; we also do not understand how habitat alterations affect potential competitive or predatory interactions with open-country raptors. Habitat preferences of Goshawks when foraging in various forest types are poorly understood. We do not know how changes in landscape pattern and habitat structure affect foraging behavior and habitat selection; our ability to predict potential impacts of habitat alterations to prey populations is limited. We currently lack estimates of population trends because migration and roadside counts have limited utility as a result of low detections and irruptive movements. Other monitoring procedures need to be developed and implemented to determine population trends. Goshawk wintering biology is almost completely unknown, as is our understanding of dispersal capabilities and mortality rates. These data are needed to manage the species. Although many studies have described nesting habitat, most used biased searching techniques to locate nests and few studies compared used habitats to those available. The degree to which biased searching hinders our understanding of nest habitat preferences is unknown; additional nest preference studies are needed and should be based on unbiased nest locations so that management recommendations are well founded.

ACKNOWLEDGMENTS

Helpful reviews were provided by Suzanne Joy, Patricia Kennedy, and Brian Woodbridge. We thank Hawk-Watch International, Hawk Mountain Sanctuary Association, Hawk Ridge Nature Reserve, and Cape May Bird Observatory for migration counts. We also thank Borror Laboratory of Bioacoustics for sonograms. Cover photo © D. R. Herr/VIREO, photographed in Denali National Park, Alaska, in July 1981.

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Appendix 1. Important prey of Northern Goshawks in North America; values indicate percent frequency (percentage of biomass) in diet.

STATE Sources ¹	Arizona A ²	B ⁴	Washington C ^{3,4}	New York D ⁴	New Mexico E ³	Oregon F ^{3,4,5}	California G ⁴	Nevada H ²
DOMINANT AVIAN PREY⁵								
American Crow (<i>Corvus brachyrhynchos</i>)		1	1	5.2				
American Robin (<i>Turdus migratorius</i>)		1	11	2.6	13.2	20		10
American Woodcock (<i>Scolopax minor</i>)				3.9		5		
Blue Grouse (<i>Dendragapus obscurus</i>)		1	2	11.7				
Blue Jay (<i>Cyanocitta cristata</i>)				3.9				
Eastern Meadowlark (<i>Sturnella magna</i>)			9			5		
Gray Jay (<i>Perisoreus canadensis</i>)						10		
Mountain Quail (<i>Oreortyx pictus</i>)						7		
Mourning Dove (<i>Zenaidura macroura</i>)						15		
Northern Flicker (<i>Colaptes auratus</i>)		11	1	5.2	26.4	2		14
Ruffed Grouse (<i>Bonasa umbellus</i>)	5.2 (1.5)		1	18.2				
Stellar's Jay (<i>Cyanocitta stelleri</i>)	10.7 (2.7)	17	7	7.8	17.0	29	16.6 (6.3)	
Unidentified birds		2	2			1		6
Unidentified grouse (Blue or Ruffed)			10	2.6		4	8.5 (3.1)	
Unidentified thrush spp.								
Unidentified woodpecker (<i>Picoides</i>), sapsuckers (<i>Sphyrapicus</i> spp.)								
Varied Thrush (<i>Ixoreus naevius</i>)		7	4			4		
Williamson's Sapsucker (<i>Sphyrapicus thyroideus</i>)								
DOMINANT MAMMALIAN PREY⁴								
Abert's squirrel (<i>Sciurus aberti</i>)		13			19.6	4		47
Belding's ground squirrel (<i>Spermophilus beldingi</i>)		11						
Black-tailed jackrabbit (<i>Lepus californicus</i>)			4					
Boreal red back vole (<i>Clethrionomys gapperi</i>)								
Cottontail (<i>Sylvilagus</i> spp.)	13.3 (26.1)		6			13	15.1 (14.7)	8
Douglas squirrel (<i>Tamiasciurus douglasii</i>)						17	14.6 (15.6)	
Golden mantled ground squirrel (<i>Spermophilus lateralis</i>)	28.0 (14.9)	5		6.5		15		
Gray squirrel (<i>Sciurus carolinensis</i>)			6					
Northern flying squirrel (<i>Glaucomys sabrinus</i>)								
Red squirrel (<i>Tamiasciurus hudsonicus</i>)	10.1 (5.8)	11		11.7	5.9			
Rock squirrel (<i>Spermophilus variegatus</i>)	5.9 (9.8)	4	3			19		
Snowshoe hare (<i>Lepus americanus</i>)	8.5 (15.0)							
Tassel-eared squirrel (<i>Sciurus aberti</i>)		22						
Unidentified rabbit or hare (<i>Sylvilagus</i> , <i>Lepus</i> spp.)	12.4 (2.0)	2	3	15.6	41.2	8		
Unidentified chipmunk (<i>Eutamias</i> spp.)						12		
Unidentified ground squirrel								
Unidentified tree squirrel (<i>Sciuridae</i>)		6			13.7	5	19.2 (19.5)	12
Western gray squirrel (<i>Sciurus griseus</i>)							3.0 (9.3)	

¹Sources: A = Boal and Mannan 1994; B = Reynolds et al. 1994; C = Fleming 1987; D = Grzybowski and Eaton 1976; E = Kennedy 1989; F = Reynolds and Meslow 1984; G = Woodbridge et al. 1988; H = Younk and Bechard 1994.

²Direct observation.

³Pellet analysis.

⁴Prey remains.

⁵Count data.

⁶Prey with frequency or percent composition > 2 for at least one study.

Appendix 2. Measurements and mass of live Northern Goshawks according to geographic region, sex, and age. Data shown as mean \pm SD (range; *n*).

Feature measured	Arizona ¹ Reynolds et al. 1994 ²	Nevada ^{2,3} Hoffman et al. 1990	Oregon ¹ Henny et al. 1985	Wisconsin ³ Mueller et al. 1976
Wing-chord length (mm)				
Male				
Basic	342 \pm 7.0 (324–362; 45)	327 \pm 6.6 (313–335; 15)	321.1 \pm 7.4 (307–336; 22)	323 \pm 4.8 (309–336; 41)
Juvenile		325 \pm 8.1 (303–337; 37)		319 \pm 6.4 (301–334; 109)
Female				
Basic	373 \pm 9.0 (350–389; 49)	357 \pm 7.8 (340–377; 31)	350.3 \pm 7.9 (340–370; 36)	353 \pm 6.2 (339–365; 60)
Juvenile		358 \pm 9.1 (340–376; 57)		346 \pm 6.9 (330–361; 52)
Tail length (cm)				
Male				
Basic	235 \pm 11.0 (213–287; 45)	227 \pm 11.2 (212–241; 7)	224.2 \pm 5.3 (212–232; 21)	230 \pm 5.4 (219–240; 41)
Juvenile		243 \pm 8.1 (223–255; 20)		239 \pm 6.1 (221–252; 106)
Female				
Basic	277 \pm 9.0 (247–290; 49)	269 \pm 5.5 (259–277; 12)	262.4 \pm 7.6 (249–280; 37)	266 \pm 7.7 (249–281; 60)
Juvenile		280 \pm 8.2 (263–295; 40)		272 \pm 7.5 (255–286; 53)
Mass (g)				
Male				
Basic	704.4 \pm 32.7 (631–774; 45)	797 \pm 47.3 (723–876; 8)	741.7 \pm 48.6 (655–838; 20)	925 \pm 61.3 (735–1099; 38)
Juvenile		748 \pm 45.5 (674–827; 26)		808 \pm 66.8 (664–988; 105)
Female				
Basic	985.5 \pm 51.9 (907–1,100; 49)	967 \pm 69.3 (866–1,108; 20)	972.8 \pm 63.0 (860–1,085; 38)	1,152 \pm 77.5 (1,005–1,364; 59)
Juvenile		942 \pm 77.7 (800–1,079; 48)		1,005 \pm 79.0 (878–1,253; 52)

¹Nesting.²All adults combined, including second-year birds.³Migrant.**ABOUT THE AUTHORS**

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